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COUNTY OF LOS ANGELES
CALIFORNIA

FINAL REPORT

WASTE WATER RECLAMATION PROJECT FOR ANTELOPE VALLEY AREA

***

THIS PROJECT WAS SUPPORTED BY DEMONSTRATION GRANT
NUMBERS WPD-50-01-64, WPD-50-02-65,
WPD-50-03-66 AND WPD-50-04-67 FROM THE
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
DEPARTMENT OF THE INTERIOR

***

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PREPARED BY

DEPARTMENT OF COUNTY ENGINEER

JOHN A. LAMBIE, COUNTY ENGINEER
AND PROJECT DIRECTOR

AUGUST, 1968

229

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CALIFORNIA

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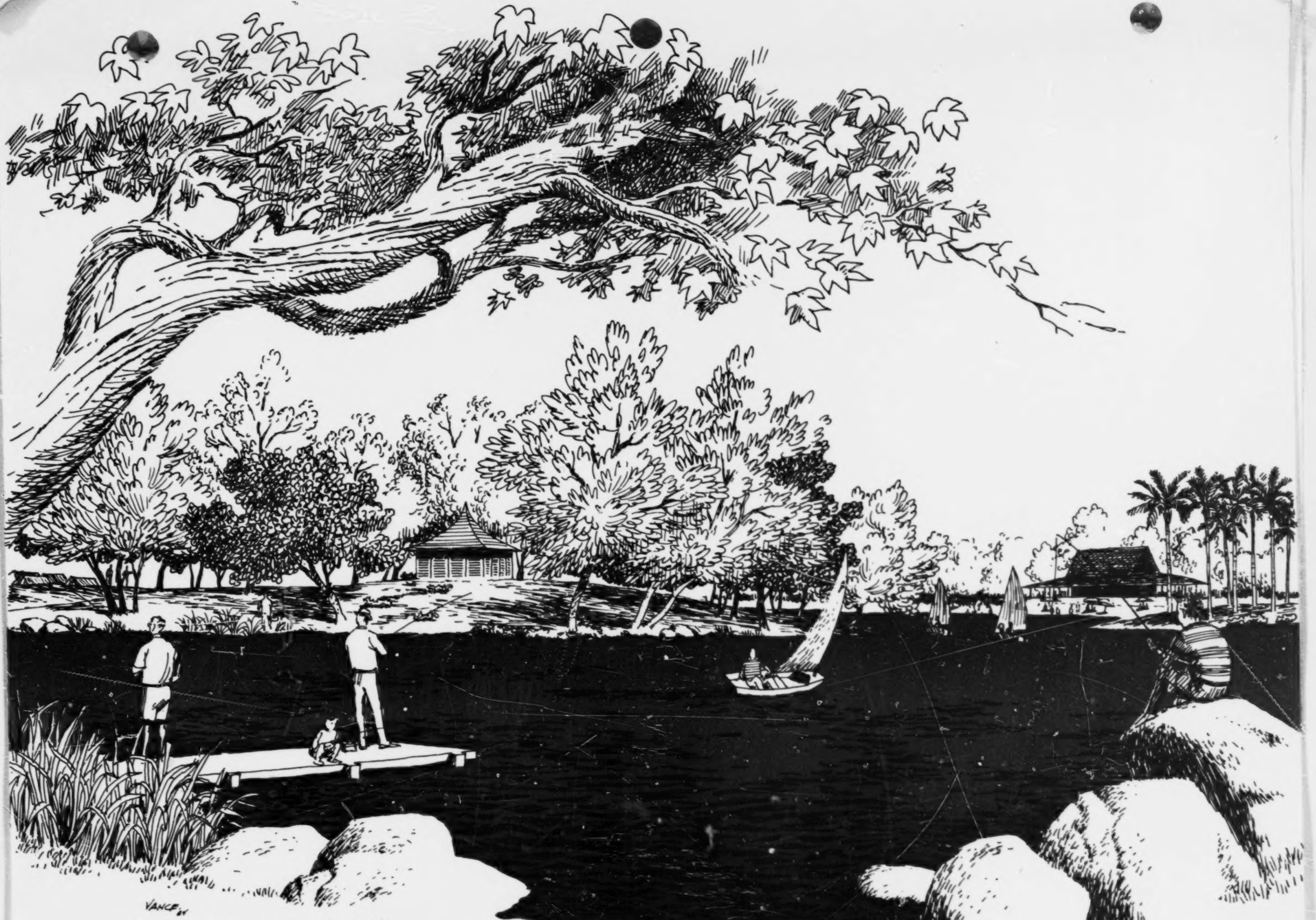

ANTELOPE VALLEY RECREATION PROJECT: The aquatic park site will provide diversified recreational facilities. The park development is being made possible through waste water reclamation.

H88

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27 Abstract
An economically feasible waste water renovation process was developed in Los Angeles County. The tertiary treated product water is pathogenically safe, esthetically pleasing and suitable for fish life. Primary use of the water will be for an aquatic recreation park, but other anticipated uses include soil reclamation, irrigation, and industrial applications. These reuses of waste water will result in the conservation of the presently diminishing fresh water supply in this arid area. All research and testing was done with the knowledge that ultimately the public must accept the concept of reuse of renovated waste water for the project to be a total success. Esthetics of the product water, including clarity, color and odor were important aspects of the treatment process. Test data demonstrate that bacteriological and viral requirements can be met. Fish have successfully survived and propagated in the test ponds. Algal growth and nutrient levels of water in the pilot ponds are considered within acceptable limits. (WRSIC Abstract)

Abstractor George Knapp 4-6-70	Institution U. S. Geological Survey, Water Resources Div.

WR:102 (REV. JULY 1969)
WRSIC

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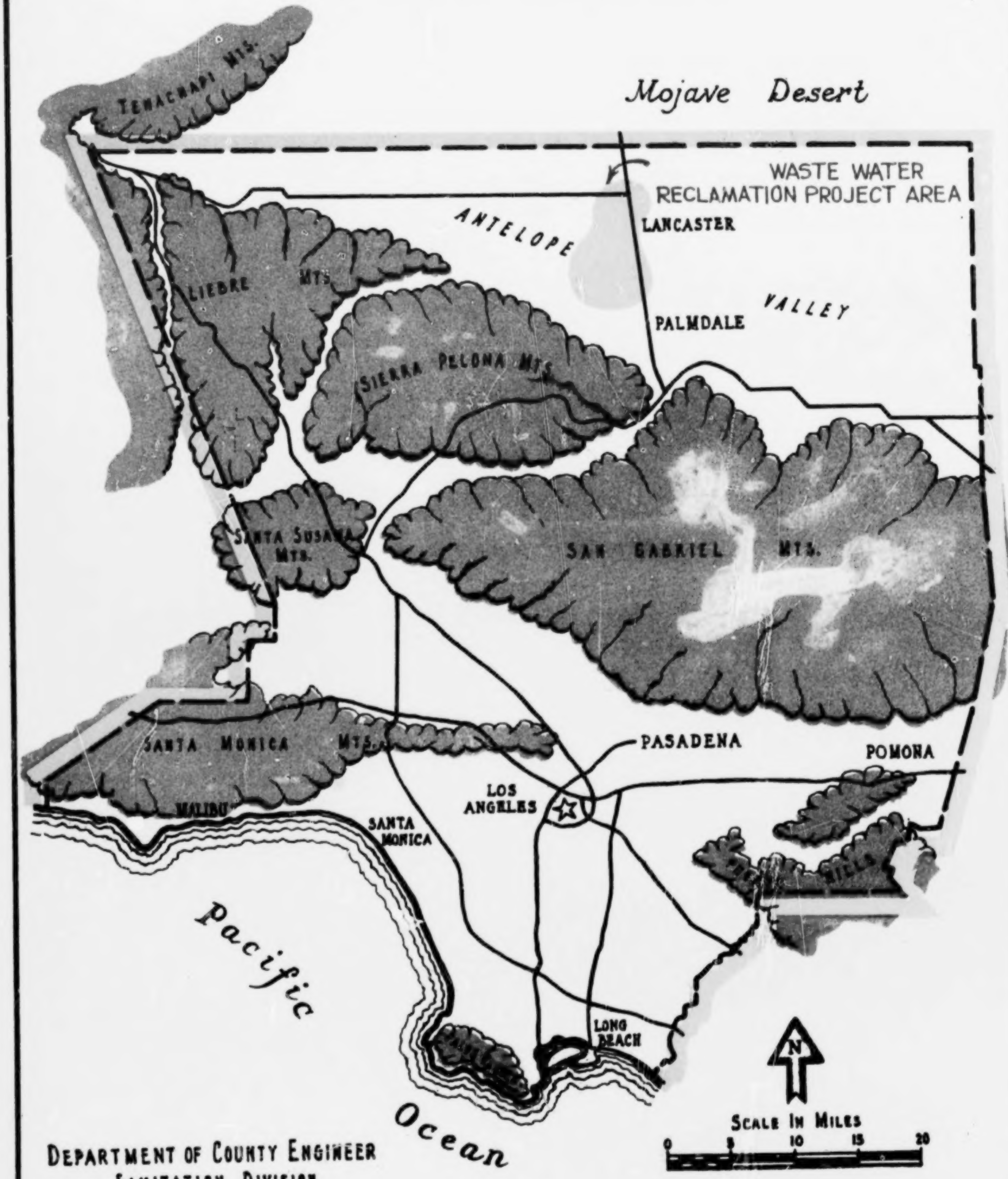
CALIFORNIA


Mojave Desert
TEHACHAPI MTS.
WASTE WATER RECLAMATION PROJECT AREA
ANTELOPE
LANCASTER
VALLEY
PALMDALE
LIEBRE MTS.
SIERRA PELONA MTS.
SANTA SUSANA MTS.
SAN GABRIEL MTS.
SANTA MONICA MTS.
PASADENA
POMONA
LOS ANGELES
MALIBU
SANTA MONICA
HILLS
Pacific
Ocean
LONG BEACH
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SCALE IN MILES
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DEPARTMENT OF COUNTY ENGINEER
SANITATION DIVISION

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ABSTRACT

An economically feasible waste water renovation process has been developed through a joint research program carried on by the Los Angeles County Department of County Engineer and the Federal Water Pollution Control Administration. The tertiary treated product water is pathogonically safe, esthetically pleasing and suitable for fish life. Primary use of the water will be for an aquatic recreation park, but other anticipated uses include soil reclamation, irrigation, and industrial applications. These reuses of waste water will result in the conservation of the presently diminishing fresh water supply in this arid area.

SUMMARY

Arid areas, such as represented by Antelope Valley in Los Angeles County, California, urgently need to conserve their rapidly diminishing water supplies. Full conservation of this vital natural resource should logically include planned reclamation and reuse of available waste waters.

Recognizing a need to conserve potable water supplies for domestic purposes, the County of Los Angeles initiated a pilot scale waste water reclamation program. Long range aims of the research were to provide water users with an abundant supply of water suited for purposes not specifically requiring potable water.

A lack of uniformly accepted operating methodology and water quality standards prompted considerable basic research of possible reclamation methods. Data developed during the testing program resulted in final design criteria for a full scale aquatic recreational park.

Primary goals of the research were to develop a suitable tertiary treatment process for the waste water. General criteria for the treatment were: To provide product water meeting bacterial and viral standards of public health agencies; provide sufficient algal and nutrient removal to prevent excessive biological growth; and to evaluate the suitability of the water for supporting fish life.

Research programs begun after initial research had been started included a study of potential industrial uses for the renovated water, and a soils reclamation study embodying waste water as a leaching agent.

All research and testing was done with the knowledge that ultimately the public must accept the concept of reuse of renovated waste water for the project to be a total success. Esthetics of the product water, including clarity, color and odor were important aspects of the treatment process.

The research programs have all been successfully completed. An economical, satisfactory tertiary treatment process has been adopted. Test data demonstrate that bacteriological and viral requirements can be met. Fish have successfully survived and propagated in the test ponds. Algal growth

and nutrient levels of water in the pilot ponds are considered within acceptable limits. A review of industrial processes suggests that many manufacturing steps could use treated water with little difficulty. A detailed soils investigation has yielded a workable method for reclaiming alkaline soils, notably utilizing treated waste water for leaching.

A detailed discussion of research methods, data and results embodies the main section of this report.

CONCLUSIONS

Economical renovation of secondarily treated waste water to meet minimum health and quality standards can be achieved. Turbidity, algae, phosphate, bacterial and viral reduction of conventional oxidation pond water has been attained through an adopted tertiary treatment process.

The pilot treatment scheme selected features treatment with 200 to 300 mg/l of alum, sedimentation, filtration, and chlorination. Phosphate is consistently reduced from 40 mg/l to less than 0.5 mg/l and algae counts are reduced from several hundred thousand to a few thousand per milliliter.

Fish pathology studies demonstrate that fish can survive and propagate in the product water. The studies showed that fish retained in the test ponds for approximately two years are as healthy as warm water fish in a natural stream.

Bacterial and viral isolations were performed by laboratory personnel from samples taken throughout the complete treatment sequence. Consistent pathogen removal was maintained.

The oxidation pond and product water has been used successfully as a leachate in conjunction with amending agents to reclaim the alkaline soils prevalent in the project site region.

It was determined that the renovated waste water can be utilized for many industrial processes, furthering the conservation concept.

Public enthusiasm and acceptance of the project goals have been most gratifying. This, coupled with the successful completion of the research and development program, makes the full-scale project practicable to construct and operate, desirable for public recreational use, and essential for the conservation of the fresh water supply in this arid region.

PART I

INTRODUCTION

A. NEED FOR PROJECT

Arid areas, such as that represented by Antelope Valley in Los Angeles County, urgently need to conserve their rapidly diminishing water supplies. Good conservation of this important resource should include planned reclamation and reuse of the available waste waters.

Demonstration of usable techniques and methods that will enable interested public agencies to make efficient use of waste water reclamation programs is certainly needed.

Recognizing a need to provide water users of the Antelope Valley area with an abundant supply of water, the County of Los Angeles initiated a program to demonstrate through pilot scale facilities a workable waste water reclamation program.

B. RESEARCH ACTIVITIES

The research and pilot plant program, conducted under a joint research contract between the County of Los Angeles and the Federal Water Pollution Control Administration, was initiated at the Los Angeles County Sanitation District No. 14 Water Pollution Control Plant (north of Lancaster, California) with three main purposes:

1. Develop a tertiary treatment process for waste water to attain sufficient algal and nutrient removal to prevent excessive biological growth.
2. Evaluate the suitability of the product water for supporting fish life.
3. Determine if bacterial and viral standards can be met as established by public health agencies.

In addition, two new programs were begun during 1965-66 under a Continuation Demonstration Project Grant from the Federal Water Pollution Control Administration. These were:

4. Determine the suitability of the renovated waste water for industrial processes.

5. Develop a process for conditioning and reclaiming alkaline soils so they will support plant life by utilizing renovated waste water.

By providing adequate quantities of treated water for uses that do not require potable supplies, conservation of existing ground waters can be attained.

Research conducted on the pilot scale provided great latitude for variations in the treatment sequence. This scheme allowed field testing of several reclamation methods with a view toward determining the best system at least cost. (Details of specific processes are included in Part II.)

In addition to the primary goals already noted, ancillary objectives included the following:

1. Determine controls for insect or noxious plant problems which are likely to occur in waste water reclamation uses.
2. Demonstrate acceptability by the public for use of reclaimed waste water in recreational projects and other activities not expressly requiring potable water.
3. Formulate pertinent design criteria. Data obtained during the research period will be an extremely useful guide in development of a full scale facility. Information assembled during the research phase provides insight as to needs for potential industrial users as well as irrigation and soil reclamation programs.

C. REVIEW OF ACCOMPLISHMENTS

Although the testing programs did not proceed entirely without difficulty, results achieved proved the feasibility of the over-all project.

The adopted tertiary treatment process will provide water of suitable quality at a reasonable cost.

Testing of the renovated water pilot test lakes has shown them to be capable of supporting fish life. Regrowth of algae has been maintained within tolerable limits.

The viral and bacterial testing programs conducted on the waste water from influent to tertiary treated effluent are very encouraging. Results indicate the product water is essentially free from viral and bacterial contamination.

Investigation of potential industrial and agricultural uses has been fruitful. It has been determined that reclaimed waste water can be used for many applications with little difficulty.

A tremendous amount of public interest has been demonstrated for the project. Numerous requests for information both by individuals and interested agencies have been received. On a number of occasions members of the County Engineer's staff have been invited to speak before civic clubs and other organizations concerning the project and future development. Many news articles have appeared in local papers, and radio commentaries have been aired.

Fish have successfully survived in the pilot ponds. During netting operations for biopsy and autopsy studies, a prodigious number of fry were discovered. Studies by a State Fish and Game Fish pathologist indicate the fish are as healthy as warm-water fish in natural streams.

An in-depth study performed by a soils consultant concludes that the barren soil in parts of the Antelope Valley Region is amenable to reclamation. A very important factor in the land reclamation is an abundant supply of water used in leaching processes.

D. PARTICIPATING AGENCIES

The entire pilot research operation was a cooperative venture. Federal agency participation came via partial funding of the research and development programs. State agencies participated through review of project goals, methods and operations as well as providing certain services. Los Angeles County provided personnel, funds and project management. A listing of participating agencies includes the following:

COUNTY AGENCIES

1. Department of County Engineer
   (Project Director and Coordinator)
2. County Health Department
3. County Sanitation Districts

FEDERAL AGENCY

1. Federal Water Pollution Control Administration,
   Department of the Interior

STATE AGENCIES

1. Lahontan Regional Water Quality Control Board
2. State Department of Health
3. State Department of Fish and Game

CONSULTANT

1. Engineering-Science, Inc.

E. SIGNIFICANT DATES

June 1964	USPHS Demonstration Grant in the amount of $45,000 approved and funded.
July 1964	Pilot facility development begun in conjunction with County Sanitation Districts.
September 1964	Nine-thousand gallon concrete-lined pilot pond filled with treated waste water.
March 1965	Fish planted in concrete pilot pond.
April 1965	Commencement of bacterial, coliform and viral studies.
June 1965	USPHS Continuation of Demonstration Grant in amount of $59,100 approved and funded.
June 1965	Two-hundred-fifty-thousand gallon earth-lined simulated lake placed in operation.
June 1965	Operation of adopted tertiary treatment pilot plant begins on seven day, 24-hour schedule.
August 1965	Fish planted in earth pond.
November 1965	Pilot treatment plant operated five days per week, alternate weeks.
November 1965	Bacteriological sampling discontinued.
January 1966	Study of potential industrial uses for reclaimed water started.
February 1966	Algae growth studies started.
March 1966	High ammonia concentration attributed to fish deaths.
March 1966	Design of full scale demonstration facility scheduled.
June 1966	USPHS Continuation of Demonstration Grant in amount of $46,000 approved and funded.
June 1966	Pilot plant research phase concluded. Plant operated part time to meet pilot pond requirements.

June 1966	Program developed for soil reclamation study.
October 1966	Lahontan Regional Water Quality Control Board approved use of treated water, based on pilot plant studies, for recreational facility.
December 1966	Greenhouse plant growth experiment conducted.
February 1967	Leaching program for soil pilot field tests started.
June 1967	FWPCA Continuation of Demonstration Grant in amount of $65,400 approved and funded.
December 1967	Soil reclamation studies concluded.
January 1968	Fish biopsy and autopsy studies conducted.
January 1968	Pilot pond ecology investigation.
March 1968	Study of potential industrial uses for reclaimed water completed.
May 1968	Radioactive tracer studies of flow rate through oxidation ponds.
June 1968	Viral studies completed.
June 1968	All programs successfully completed.

PART II

TERTIARY TREATMENT PROCESSES

A. OBJECTIVES

The principal goal of the pilot tertiary treatment research was to show that treated waste water could be produced economically while meeting required quality standards. This research program was accomplished by County Sanitation Districts personnel.

It was desired that the product water would be of reasonably high quality, low in dissolved salts and nutrients, while fully oxygenated. The water needed to be pleasing esthetically, both in clarity and odor for full public acceptance. Pathogen removal was of course a primary concern for users' health. Finally, the water was intended to be capable of sustaining fish life in the recreational facility.

Initial review of literature displayed a lack of uniformly accepted minimum quality requirements. It was decided therefore, to make the testing procedures variable to allow for changing conditions and changes indicated by the processes in progress.

Information obtained from studies made by Sawyer (1947) and Malhatra (1964), correspondence with officials of the Robert A. Taft Sanitary Engineering Center, and recent reports of the operations of the Santee County Water District reclaimed water recreation lakes were consulted in order to establish the following initial minimum quality standards:

1. Turbidity of less than 10 Jackson turbidity units (JTU).
2. Phosphate concentration of less than 2 mg/l as PO_4.
3. pH of less than 8.0.
4. Low concentration of chemical oxygen demand (COD) and biological oxygen demand (BOD).
5. Algae counts less than 10,000 per milliliter.
6. Coliform and virus determinations to meet requirements of the County Health Officer.

Experience gained during the operation of the pilot treatment process has shown that the phosphate criteria should be reduced from 2 mg/l to 0.5 mg/l, or less, for algae regrowth control. This objective can be economically attained.

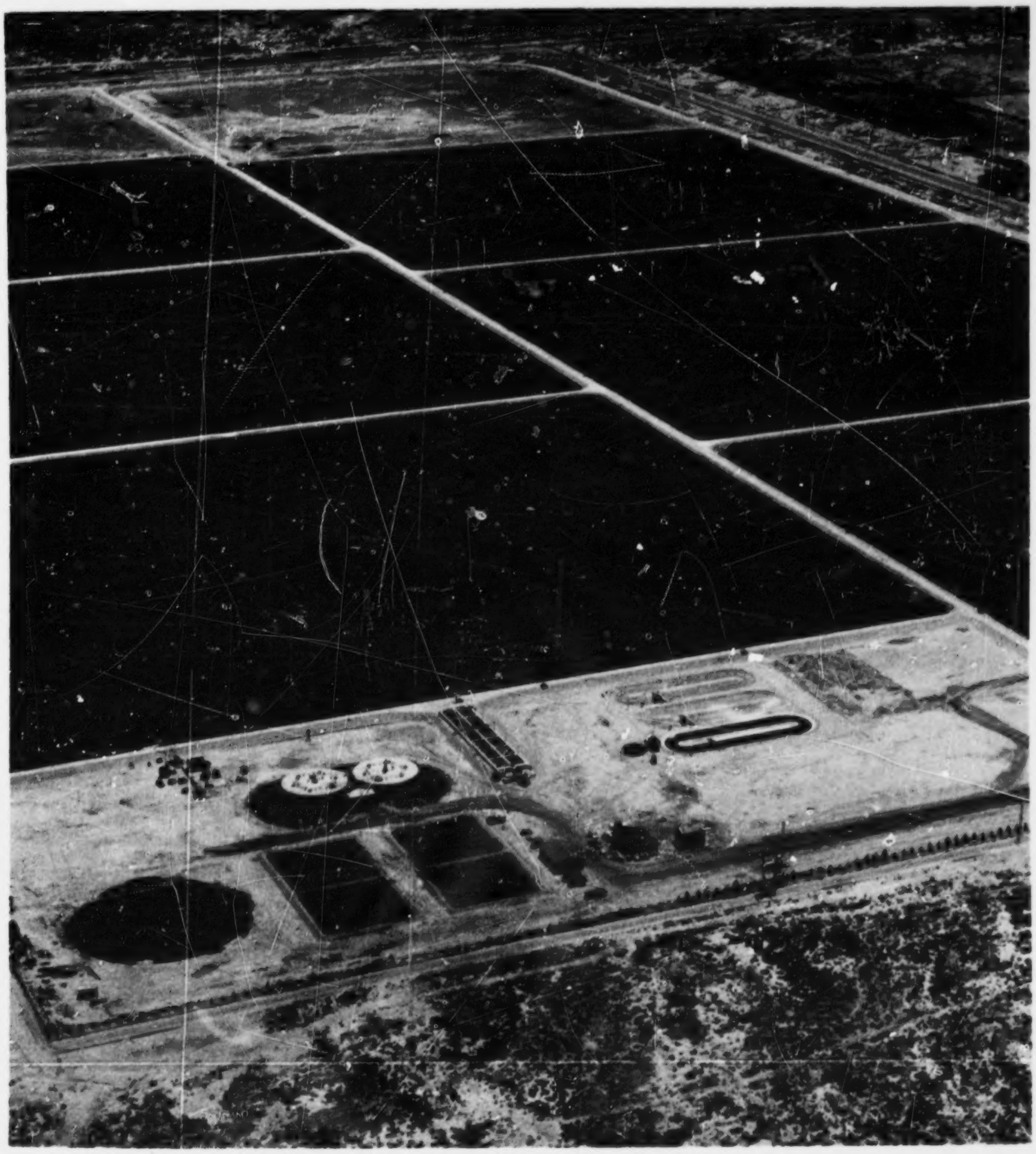
In general, the product water is of superior quality than the minimum quality requirements. Average turbidity is approximately 5 JTU, providing a clear and colorless water. Water of such a pleasing esthetic quality will be more easily accepted by the public.

At the start of basic testing (1964), the local Health Department established as minimum requirement standards derived from Sections 7957 to 7960 of Title 17, California Administrative Code. Section 7958 stipulates that the most probable number of coliform organisms be less than 1000 per ml. (10 per ml.) Sections 8025 to 8050, amended to Title 17 mid-1968, provide new and definite standards for waste water recreational facilities. An important consideration of the new sections is that treated water intended for use in a recreational facility shall contain not more than 2.2 coliform organisms per 100 ml. (MPN). The adopted treatment process water has consistently exhibited E. Coli counts of 1.8, or less, per 100 ml.

B. INVESTIGATED PROCESSES

At the present time, approximately 3 mgd of waste water is received at the Sanitation District No. 14 plant to be given primary and secondary treatment. Primary treatment consists of plain sedimentation to remove settleable suspended solids and floatable materials. The effluent is then discharged into oxidation Pond 1 for secondary treatment. The waste water travels through Ponds 2, 4, and 3 which takes approximately 60 days. Organic matter is biologically decomposed by bacteria supplied with oxygen produced by free floating algae. Effluent not evaporated in the ponds during this period is discharged from Pond 3 to Ponds 5, 6, 7, and 8 to permit additional evaporation or off-site disposal. The picture on the next page shows the Sanitation Districts Plant No. 14 layout.

Since oxidation Pond No. 3 is normally the last pond in the treatment series, its effluent was used during the research and development phase. Pond 3 is scheduled for eventual use in the aquatic recreational facilities proposed for the Antelope Valley Waste Water Reclamation Project.



COUNTY SANITATION DISTRICT NO. 14
WATER POLLUTION CONTROL PLANT

Looking southeast. Treatment facilities for present influent of three million gallons daily in foreground. 240 acres of Oxidation Ponds. Water now wasted by evaporation to the atmosphere.

Table 1 on the next page summarizes the average characteristics of oxidation Pond 3 water. Figure 1 on the following page shows the general layout of oxidation ponds and the research project site and facilities. The pilot work area located on the west side of Pond 1 was adequately equipped to handle numerous processes concurrently.

The most important treatment phase in the tertiary treatment process is the removal of phosphates. This treatment process provides control of algae and bacteria. The total phosphate concentration is higher in the winter and spring than in the summer and fall. Other periodic variations between the colder and warmer seasons which are important to the tertiary processes include:

1. Temperature, which varies from 6° to 30° C.
2. pH, which ranges from 7.5 to 9.6.
3. COD, which ranges from 300 mg/l to 200 mg/l during the summer.
4. BOD, which ranges from 50 mg/l (winter) to 40 mg/l.
5. Suspended solids which decrease from 100 mg/l to 75 mg/l.
6. Dissolved solids which decrease from 640 to 570 mg/l.
7. Turbidity, which ranges from 90 to 170 JTU in the winter and from 40 to 150 JTU in the summer.

At the beginning of the tertiary treatment testing series, it was hoped to remove algae separately from the dissolved nutrients. The recovered algae could then be processed and marketed as a nutrious poultry feed. A small micro-strainer (23-micron mesh), a pressure sand filter, and three types of diatomaceous earth filters were studied. All of the investigated algae recovering schemes proved to be unsuccessful. The micro-strainer was totally inadequate due to fouling. The pressure sand filter produced good removal but not enough to be economical. The D-E filters also removed the algae quite well, but left the product water with a distinct color and high turbidity.

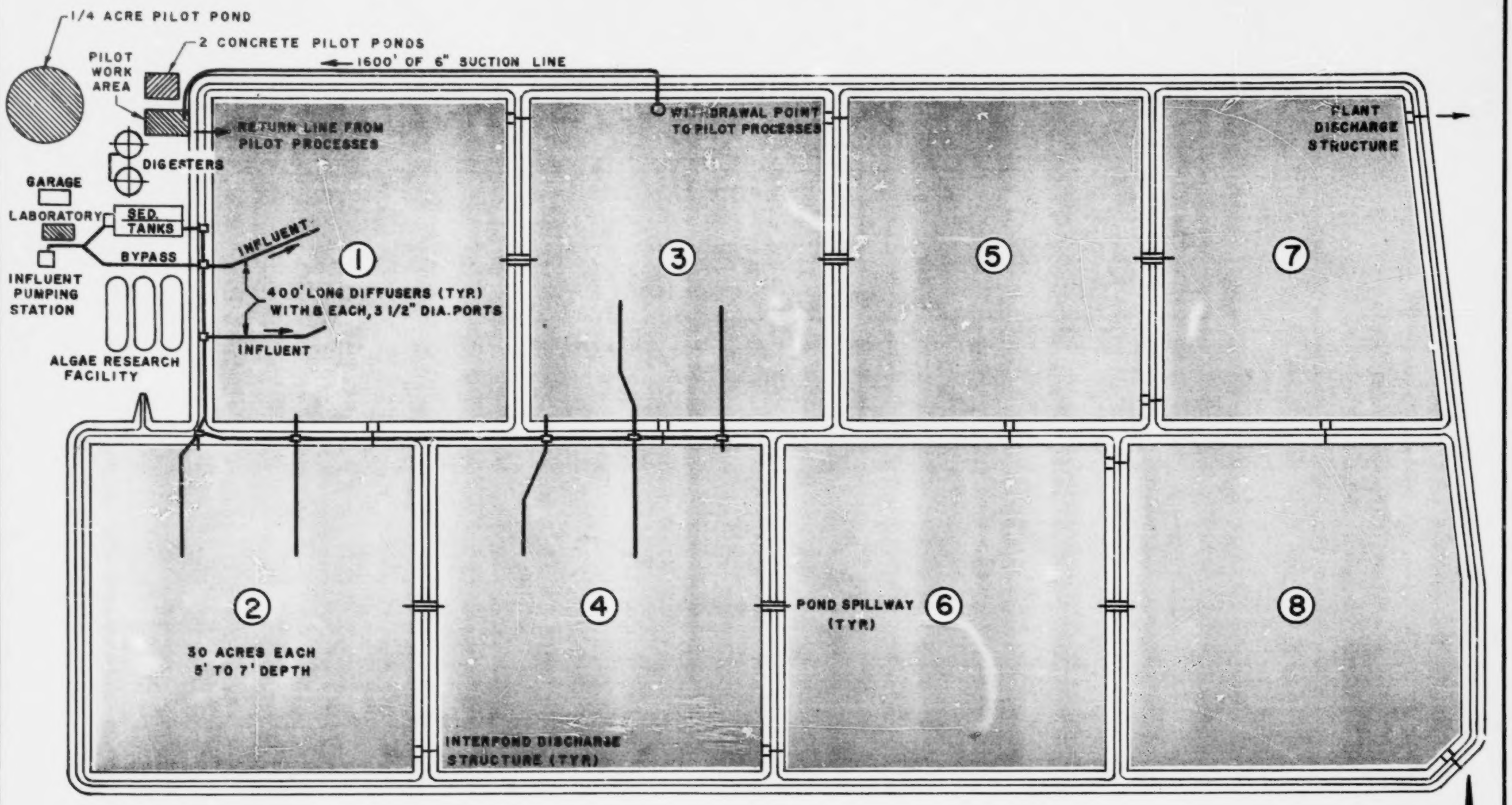
[illegible]

AVERAGE CHARACTERISTICS OF OXIDATION POND 3 WATER

	Units	February-June Average	February-June Max	February-June Min	July-January Average	July-January Max	July-January Min
pH		8.3	8.6	7.9	8.8	9.4	8.3
Temperature	°C	8	19	6	16	33	9
C.O.D.	mg/l	300	440	210	200	240	180
B.O.D.	mg/l	50	57	17	40	47	26
Solids, Suspended	mg/l	100	115	55	75	95	45
Solids, Dissolved	mg/l	640	770	570	570	640	500
Solids, Total	mg/l	740	870	630	645	690	560
Algae, Counts	10^3 cts/ml	200	630	35	200	360	55
Algae, Predominant Genera		Scenedesmus			Scenedesmus		
Turbidity	J.T.U.*	110	170	90	110	150	50
Hardness (as $CaCO_3$)	mg/l	85	130	56	70	80	56
Alkalinity, Hydroxide	mg/l	0	0	0	0	0	0
Alkalinity, Carbonate	mg/l	3	10	0	30	80	0
Alkalinity, Bicarbonate	mg/l	270	290	250	200	250	150
Alkalinity, Total	mg/l	273	290	250	230	250	220
Phosphate (as PO_4)	mg/l	47	50	40	39	43	30
Nitrogen, Organic	mg/l	10	13	7	7	9	4
Nitrogen, Ammonia	mg/l	15	22	10	4	16	0.5
Nitrogen, Nitrate	mg/l	1	2	0.2	1	2	0.2
Nitrogen, Nitrite	mg/l	0.02	0.04	0	0.02	0.04	0
A B S	mg/l	5.5	7	4	5.5	7	4
Dissolved Oxygen	mg/l	-	24	0.1	-	36	0.8

* Jackson Candle Turbidity Units

COMPILED BY COUNTY SANITATION DISTRICTS


1/4 ACRE PILOT POND
2 CONCRETE PILOT PONDS
PILOT WORK AREA
← 1600' OF 6" SUCTION LINE
RETURN LINE FROM PILOT PROCESSES
WITHDRAWAL POINT TO PILOT PROCESSES
PLANT DISCHARGE STRUCTURE
DIGESTERS
GARAGE
LABORATORY
SED. TANKS
BYPASS
INFLUENT
INFLUENT PUMPING STATION
400' LONG DIFFUSERS (TYR) WITH 8 EACH, 3 1/2" DIA. PORTS
INFLUENT
ALGAE RESEARCH FACILITY
①
③
⑤
⑦
②
30 ACRES EACH 5' TO 7' DEPTH
④
POND SPILLWAY (TYR)
⑥
⑧
INTERPOND DISCHARGE STRUCTURE (TYR)
N

DISTRICT 14 WATER POLLUTION CONTROL PLANT

GENERAL LAYOUT OF

OXIDATION PONDS 1 THRU 8 AND THE STUDY AREA

SCALE 1"=500'

FIG. 1

The oxidation pond water, as indicated in Table 1, has high concentrations of algae which must be removed before water clarity can be attained and fish life can be satisfactorily propagated. Algae are detrimental since they contribute toward a high pH and nocturnal depletion of oxygen. If nutrients remain in the effluent in sufficient concentrations, they will also result in extensive algal blooms in the proposed recreational lakes.

The tertiary treatment processes for algal removal developed and studied include chemical treatment for killing the algae, mechanical treatment for harvesting algae, and filtration for polishing the effluent. In conjunction with the above research, supplemental investigations were made for nutrient removal by chemical and/or physical means.

C. COAGULANT STUDIES

Laboratory studies conducted at the site, an essential phase of the program, were not only pointed towards obtaining basic data on the ponds and to monitor the pilot work, but also to determine the most effective coagulants and coagulant aids, their required dosages, the best flocculating conditions, and relative costs.

The test equipment used for the coagulation determinations consisted of a ten-paddle stirrer with a variable drive. The tests were done on oxidation Pond 3 water, using procedures suggested by Cohen (1957).

In order to obtain a maximum number of samples, the amount of coagulation was estimated by a rapid turbidity reduction measurement. Additional chemical analysis were performed on promising samples. The most promising coagulants were:

1. Aluminum Sulfate (Alum) - $Al_2(SO_4)_3$ (commercial grade) with and without pH adjustments and other coagulant aids.
2. Ferric Sulfate - $Fe_2(SO_4)_3$, 70% pure, 30% inert.
3. Lime - both hi-calcium (90% $Ca(OH)_2$) and the less expensive Dolomite (58% $Ca(OH)_2$ and 41% $Mg(OH)_2$.
4. Dow C-31 and Dow NC-1118-cationic polyelectrolyte.
5. UCAR 149 (Union Carbide Co.)-cationic polyelectrolyte.
6. Nalco 600-cationic polyelectrolyte.

Most of the coagulation tests were made using alum, lime, and the various cationic polyelectrolytes as coagulants. Sulfuric acid and carbon dioxide were used for pH adjustment in conjunction with the alum coagulation.

Figure 2 (page 18) shows the test results for the primary coagulants in relation to costs, which are based on the chemical prices presented in Table 2. Although Dolomitic lime was used in the cost analysis and hi-calcium lime was actually used in pilot studies, the jar tests showed the two products to be equally effective at equivalent dosages.

Among the primary coagulants tested, aluminum sulfate was found to be the most effective. Lime coagulation, on the other hand, while only a little less effective, was more costly than aluminum sulfate, chiefly due to the need for subsequent pH reduction. During the colder seasons the alum reduced total phosphates significantly better than the lime.

Figure 3 shows the typical change of jar test curves for lower dosages of aluminum sulfate coagulant, along with some pilot dissolved air flotation data for the period between July 1964 and January 1965. Figure 4 shows the similar relationships for lime coagulation jar and pilot tests.

Cationic polyelectrolyte coagulants tested, several of which are listed above, materially reduced the quantities of aluminum sulfate required to accomplish turbidity objectives, which is established as less than 10 JTU (Jackson Turbidity Units). The relationships between Chemical Costs and Percent Turbidity Reduction for aluminum sulfate alone and for three combinations of coagulant aids are presented in Figure 5. It appears that chemical costs could be substantially reduced by using aluminum sulfate in combination with Dow C-31. However, no savings could actually be effected since the Dow C-31 does not remove soluble phosphate, the removal of which is considered important.

The jar test studies were also planned to aid in determination of optimum conditions for successful alum coagulation of Pond 3 water for phosphate removal. Results of the tests indicate that both with or without the addition of acid or base to alter the pH and alkalinity, phosphate residuals were minimum when the final pH was approximately 6.0. Increasing the alum dosage from 150 to 300 mg/l also decreased the minimum phosphate residual. Other researchers have determined that the equilibrium constant for alum indicates that phosphates can be removed to 0.04 mg/l, and that pH for optimum removal is close to 6.0.

TABLE 2

SUMMARY OF CHEMICAL COSTS

	Unit Costs		Cost Per Million Gallons
	Per Ton	Per Pound	@ 1 mg/l
High Calcium Hydrated Lime ($Ca(OH)_2$)	$ 27.80	$0.0139	0.116
Local Hydrated Dolomite Lime ($Ca(OH)_2$ and $Mg(OH)_2$)	20.00	0.010	0.0834
Aluminum Sulfate (Commercial Grade) ($Al_2(SO_4)_3$)	48.40	0.0242	0.202
Sulfuric Acid 66 Baume (H_2SO_4)	31.18	0.0159	0.13
Ferric Sulfate ($Fe_2(SO_4)_3$)	60.00	0.030	0.2502
UCAR-149 (Union Carbide)	2,000.00	1.00	8.34
Dow C-31	680.00	0.34	2.89
Dow NC-1118	500.00	0.25	2.09
Superfloc-16 (American Cyanamid)	2,500.00	1.25	10.40
Chlorine (Ton Cylinders)	140.00	0.07	0.58
Carbon Dioxide (Obtained by Burning Available Digester Gas)	20.00	0.01	0.0834

Notes: 1. All prices are f.o.b. Lancaster, California

2. On dry weight basis.

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COST VS. REMOVAL EFFICIENCY FOR PRIMARY COAGULANTS
BASED ON LABORATORY JAR TESTS
MARCH, 1964 TO MAY, 1964

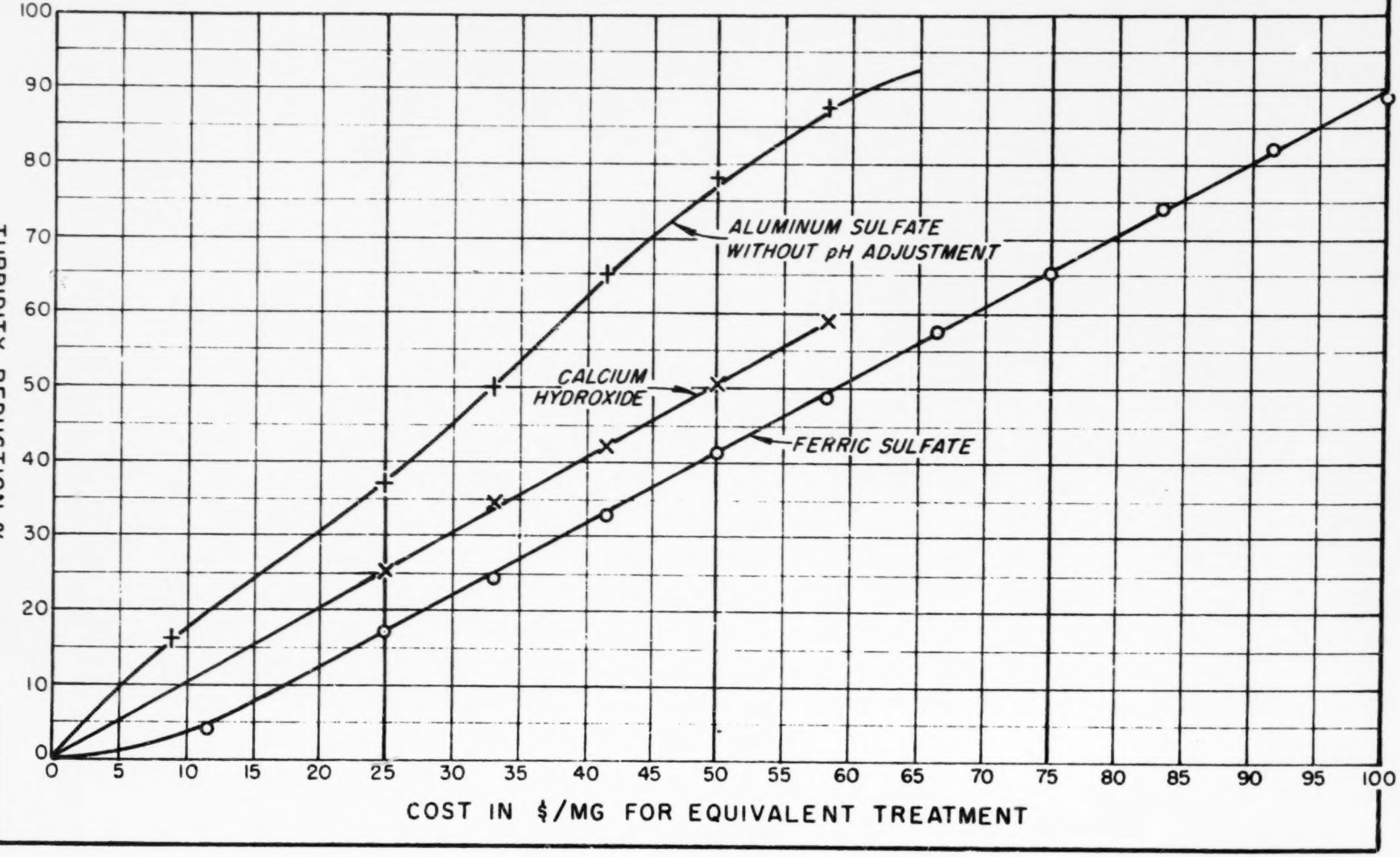

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FIG. 2

FINAL TURBIDITY vs. ALUMINUM SULFATE DOSAGE

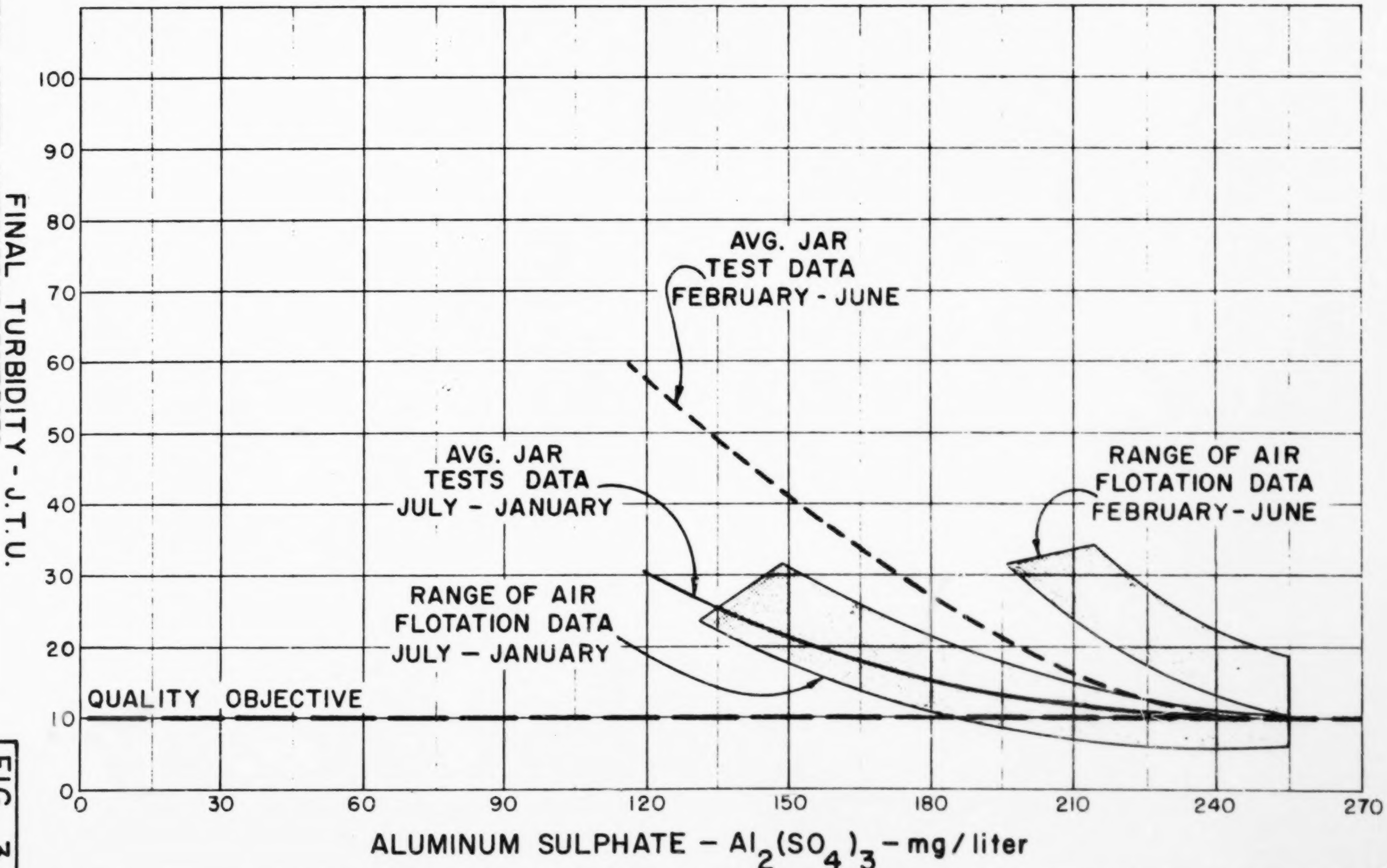

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FIG. 3

FINAL TURBIDITY vs. CALCIUM HYDROXIDE DOSAGE

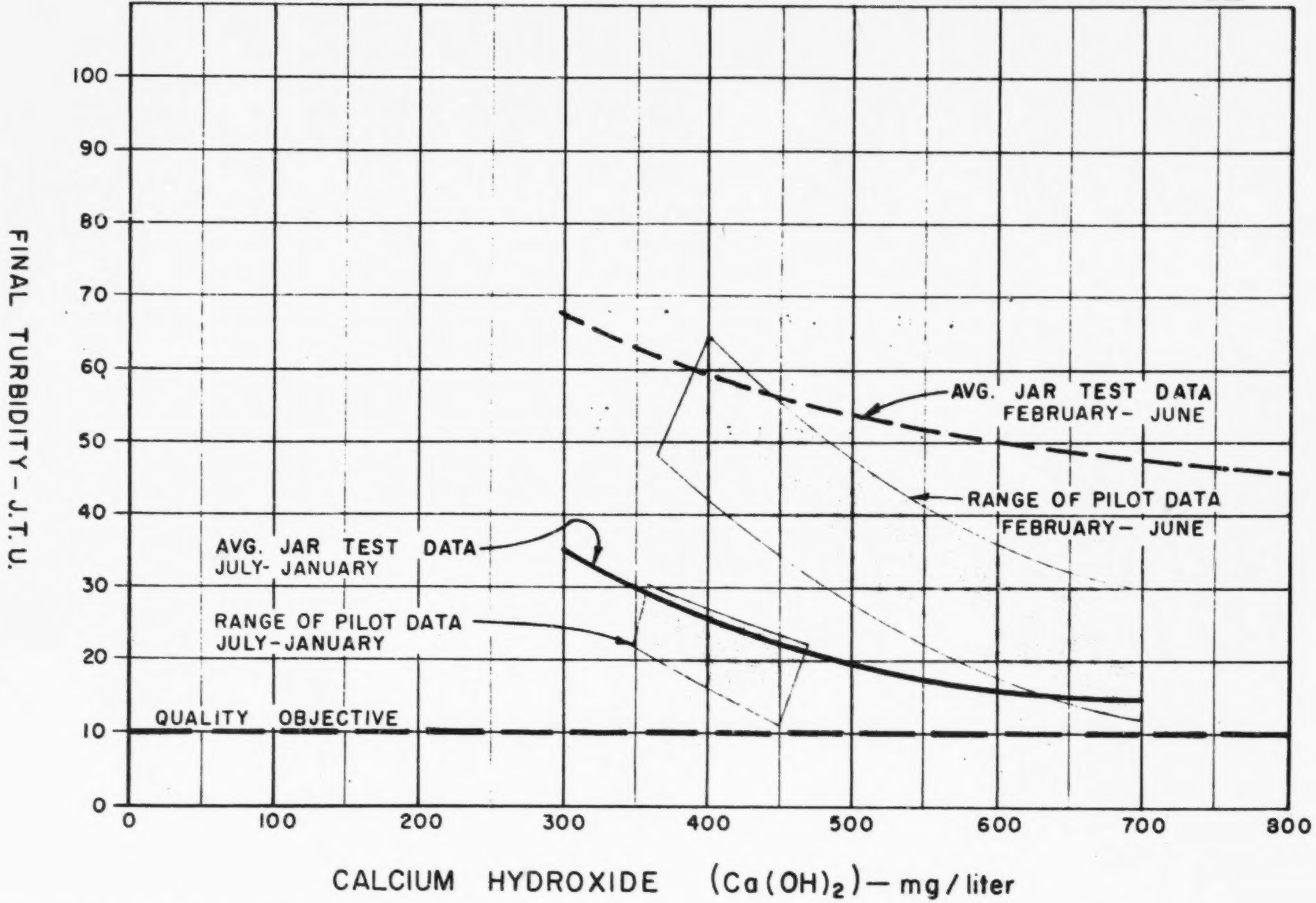

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FIG. 4

RELATIVE AFFECTIVENESS OF ALUMINUM SULFATE AND DOW C-31 — JAR TESTS

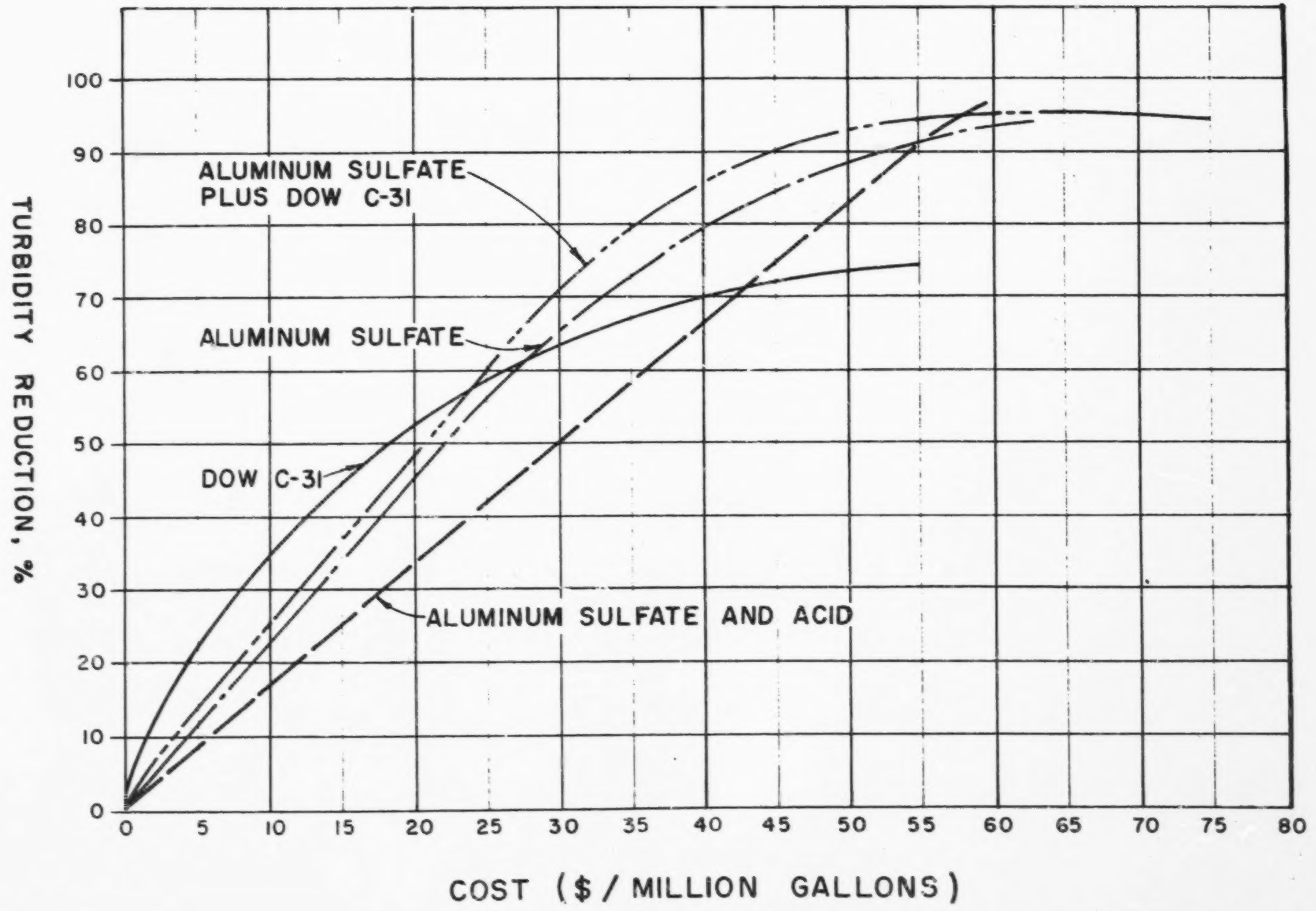

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FIG. 5

D. CHEMICAL TREATMENTS

In spite of the economies to be gained by both clarifying and removing nutrients in a single process, the pilot studies indicated the need for two separate treatment steps. The first step includes chemical coagulation, flocculation and clarification of the water. The second step involves filtration and chlorination.

1. FIRST STEP PROCESSES

Initially, the quality objectives for the chemical processes were a turbidity of 20 JTU or less and total phosphate concentration of less than 2 mg/l. Subsequent algal regrowth led to the decision to lower total phosphate levels to 0.5 mg/l. Phosphate reduction was achieved by larger doses of alum. A further benefit of the larger alum doses was reduction of turbidity readings to 5-10 JTU. (Turbidity was used to compare the relative effectiveness of the pilot processes.) The following types of pilot equipment were tested:

a. Water Treatment Plant - A completely self-contained, truck-mounted water purification unit of 25 GPM rated capacity loaned to the project by the U.S. Army. It features an upflow clarifier with a central mixing and flocculating chamber. Results were not satisfactory because of the release of super-saturated dissolved oxygen which bouyed the floc to the surface.

b. High Density Solids Contact Clarifier - A complete lime coagulation and recarbonation water treatment unit of 15 GMP rated capacity with provision for sludge recycle and auxiliary chemical addition. The first of two ten-foot tall, four-foot diameter vertical columns contains rapid mix, coagulation and flocculation zones near the top with upflow clarifier and sludge collection zones in the bottom. The second column or recarbonator, contains inverted trays to accomplish pH adjustment by CO_2 addition and a chamber for supplementary settling. The unit did not operate successfully at its rated capacity but did a very adequate job at 10 to 15 GPM.

c. Dissolved Air Flotation - Pilot units in two sizes were used in the study:

(1) One square foot unit - rated capacity of 0.3 to 3.0 GPM, air dissolved into auxiliary water stream at 60-70 psi, manually skimmed, operated at about 1 GPM.

(2) A six-foot diameter, 27-square foot x six-foot deep air flotation unit rated at 50 GPM. Coagulated water entered a supersaturated mixing chamber in the center of the six-foot high tank. Air dissolved into the recycle water is released in small bubbles that lift the floc to the top where it is skimmed into a trough. The clarified water flows to the bottom of the tank and up to and over a circular weir around its periphery. The unit was operated at flow rates between 20 and 50 GPM with most runs at 30 or 40 GPM. The recycle stream was varied from 10 to 25 GPM at pressures of 40 and 20 psi, respectively. Air at about 15 cubic feet per hour was introduced by injection into the suction line of the recycle pump.

d. Sedimentation - A 1200-gallon circular tank, four feet deep and 7.5 feet in diameter was baffled to operate as a horizontal-flow sedimentation tank. At 11 GPM there was a two-hour detention time and an overflow rate of 340 gpd/sq.ft. A submerged discharge protected the effluent from floating algae. Results of the tests showed that it was justified to build a larger unit for further testing.

The high density solids contact clarifer, air flotation, and sedimentation processes were found to be technically feasible. The sedimentation tank test results were almost identical to those obtained in the air flotation unit in contrast to the very poor results obtained in the truck-mounted upflow clarifier used in the early part of the study. Photographs of these units are included at the end of this section. Table 3 presents results of the various treatment processes.

The pilot plant tests substantiated the jar tests results in that alum remained the most effective chemical coagulant. Therefore, both air flotation and horizontal sedimentation with alum as primary coagulants were chosen as the most acceptable processes.

TABLE 3

SUMMARY OF SIGNIFICANT PILOT PROCESS DATA

Process	Coagulants	Study Period	Dosage (mg/l to achieve:		Approximate Coagulant Costs
			$PO_4 \leq 2$	Turbidity ≤ 10	$ per MG
High Density Solids Contact Unit	Lime	Feb. to June	650	650	70
	Lime	July to Jan.	450	400	50
Air Flotation	Lime	Feb. to June		600	65
	Lime	July to Jan.	600	400	65
	Aluminum Sulfate	Feb. to June	250	250	50
	Aluminum Sulfate	July to Jan.	180	180	35
	Alum Sulfate plus Dow C-31 or NC-1118	Feb. to June	250	200	50
		Feb. to June	0	4	
	Alum Sulfate plus Dow C-31 or NC-1118	July to Jan.	200	100	40
		July to Jan.	0	4	
	Alum Sulfate plus Sulfuric Acid	Feb. to June	250	200	45
		Feb. to June	0	50	

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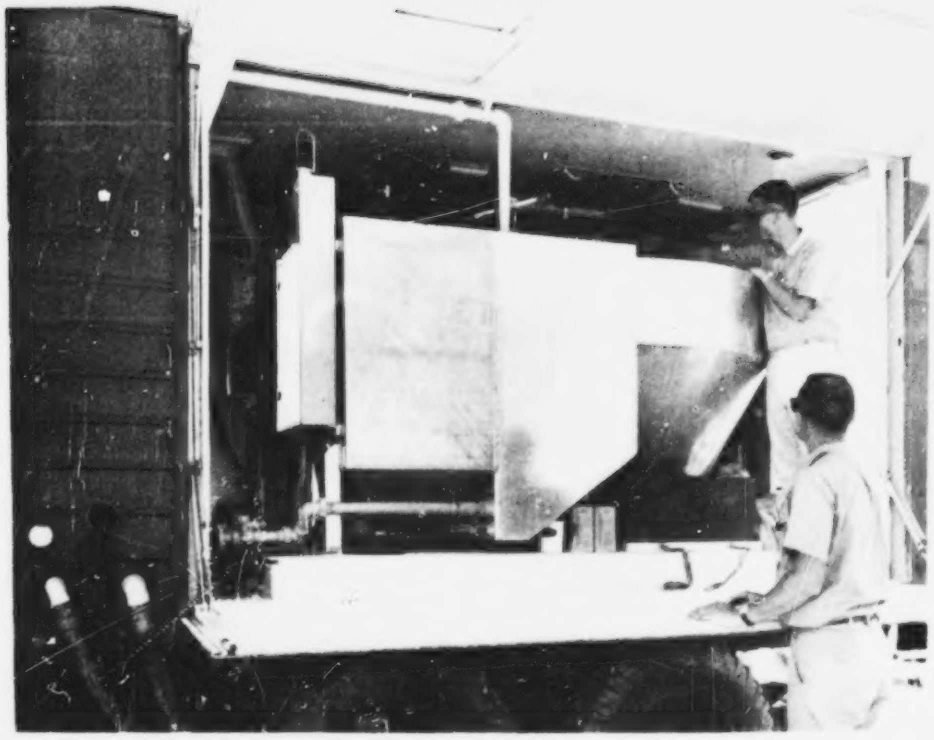
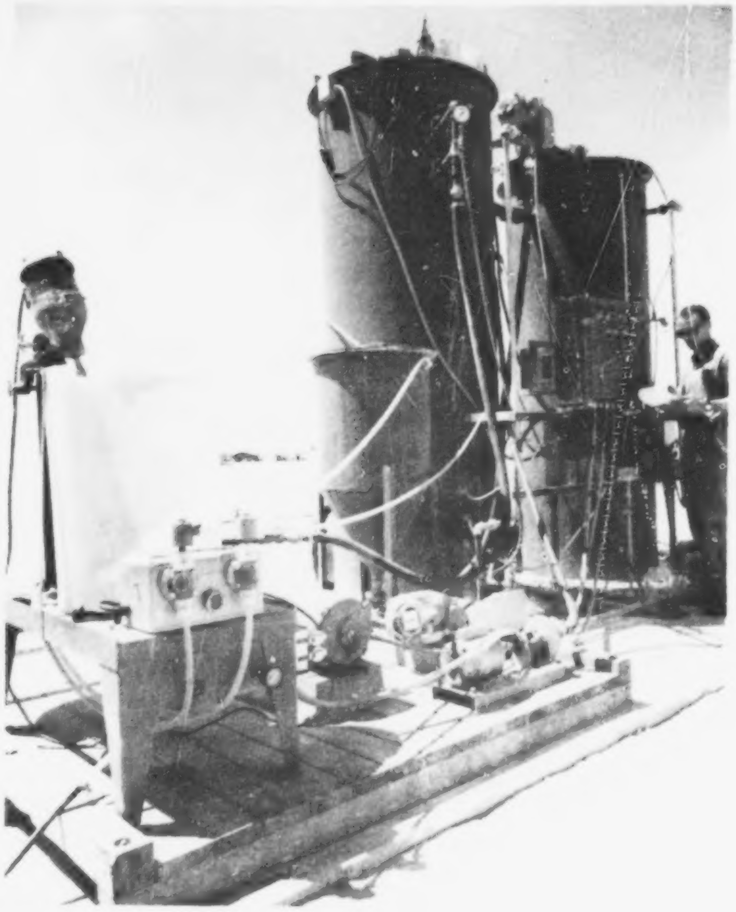
VIEW OF PILOT PLANT FACILITIES
AND PONDS LOOKING NORTHWEST
FROM OXIDATION POND NO. 1 DIKE.

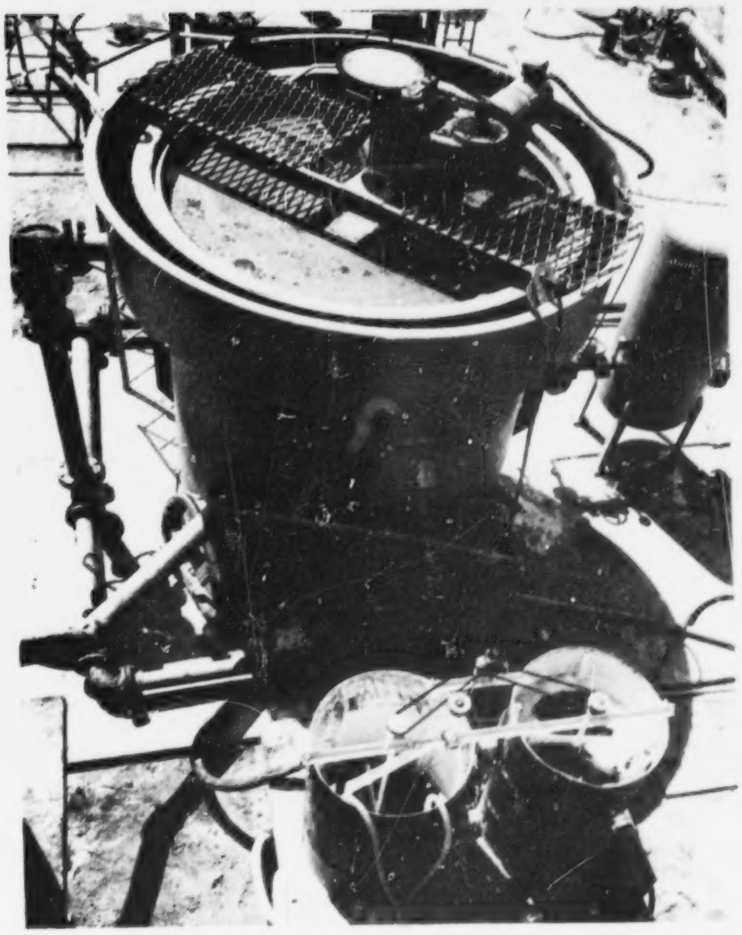
PERFORMING COD TEST IN
PROJECT LABORATORY AT
TREATMENT-PLANT SITE.



WATER PURIFICATION UNIT
FEATURING UP-FLOW CLARIFIER
AND DIATOMACEOUS EARTH FILTER
MOUNTED ON U.S. ARMY TRUCK.



HIGH DENSITY SOLIDS CONTACT
CLARIFIER AND RECARBONATION
TANK.



SIX-FOOT DIAMETER DISSOLVED AIR FLOTATION UNIT WITH POLYELECTROLYTE MIXING TANKS IN FOREGROUND.

NEW SEDIMENTATION TANK UNIT.

2. SECOND STEP PROCESSES

Polishing of primary process effluent by filtration is required to provide a safety factor for the primary process and to produce a water of such clarity that its appearance will be pleasing to the public. It would be more costly to produce water of equivalent quality by coagulation alone. The following types of equipment were tested:

a. Diatomaceous Earth Filters

(1) A low pressure reversible cake DE filter of 0.5 to 3 GPM capacity, operated at approximately 1 GPM for pilot tests.

(2) The truck-mounted 25 square foot pressure filter.

(3) A wound wire pressure filter.

(4) A vertical leaf swimming pool pressure filter.

(5) A 1 square foot bench scale pressure filter.

(6) A 50 square foot tube and shell pressure filter.

b. Sand Filters

(1) A two stage pressure sand filter, two-foot depth and 2.2 square foot serface area per stage.

(2) PHS 3½-inch diameter, 0.06 square foot lucite gravity sand and dual media filter columns.

(3) A 12 square foot gravity sand or dual media (anthrafelt-sand) filter.

Diatomaceous earth filter effluents of all types were consistently better than effluents from the dual media or pressure sand filters. However, DE filter cycles never exceeded three hours resulting in excessive DE usage and costs estimated between $80.00 and $200.00 per million gallons filtered. The reason for the short filter cycles is the blinding of the filter by algae and other particulate matter not removed in the first step separation process. The compressibility of algae cells contributes to the rapid blinding in spite of body feed rates of up to 90 mg/l and influent water turbidities as low as 3 JTU.

> Pressure sand and dual media filtration both reduce influent turbidities by 25 to 50% which results in filter effluents with turbidities of 10 or less if the first step process meets its turbidity objective of 20 JTU. Longer operating cycles and the ability to reuse the filter media on the sand filters provides a substantial cost advantage over the DE units.

Tabulation of the average results obtained with these filters is presented in Table 4. Pictures are included on the following page. A diagramatic layout of the various tertiary treatment methods is shown on page 32.

E. ADOPTED TERTIARY TREATMENT PROCESS

The field pilot treatment studies were in operation for more than a year producing reclaimed water for evaluation in the pilot ponds. Based on the results of the field pilot studies and data obtained in the laboratory, the most efficient and economical treatment process has been adopted. This process produces a suitable effluent by eliminating sufficient amounts of suspended solids, algae, dissolved nutrients and harmful pathogenic organisms. The features of the adopted process are:

1. Source water taken from oxidation pond after 60-day detention period.
2. Coagulation with approximately 300 mg/l of commercial grade aluminum sulfate.
3. Sedimentation with an overflow rate of about 500 gpd/sq.ft.
4. Filtration through a dual media gravity anthracite-sand filter.
5. Chlorination at about 15 mg/l using a liquid chlorine solution.
6. Minimum 8.4 hour detention in a chlorine contract chamber.
7. Skimmings and sludge from the sedimentation tank and backwash from the filter returned to the treatment plant.

A Flow Diagram for this process is shown in Figure 6. The characteristics of the renovated waste water obtained by the above process appear in Table 5.

TABLE 4

COMPARISON OF STEP 2 FILTRATION PROCESSES

	Per Cent of Time Filtration Effluent $<$10 J.T.U. for Influents $<$20 J.T.U.	Flow Rates GPM/sq.ft.	Filtration Cycles (hours)
Diatomaceous Earth (Pressure or reversible cake filtration) using Celite 545 D.E.	100	0.8 to 1	less than 3
Pressure Sand (Two stages in series; 2 ft. of No. 20 (0.45 mm) and 2 ft. of No. 47 (0.16 mm) sand)	83	15	4
Dual Media 8" of 1½ grade Anthrafelt (0.87 mm) over:			
10" of No. 16 sand (0.70mm)	84	3	24
10" of No. 20 sand (0.45mm)	100	3	12
10" of No. 30 sand (0.27mm)	98	3	8

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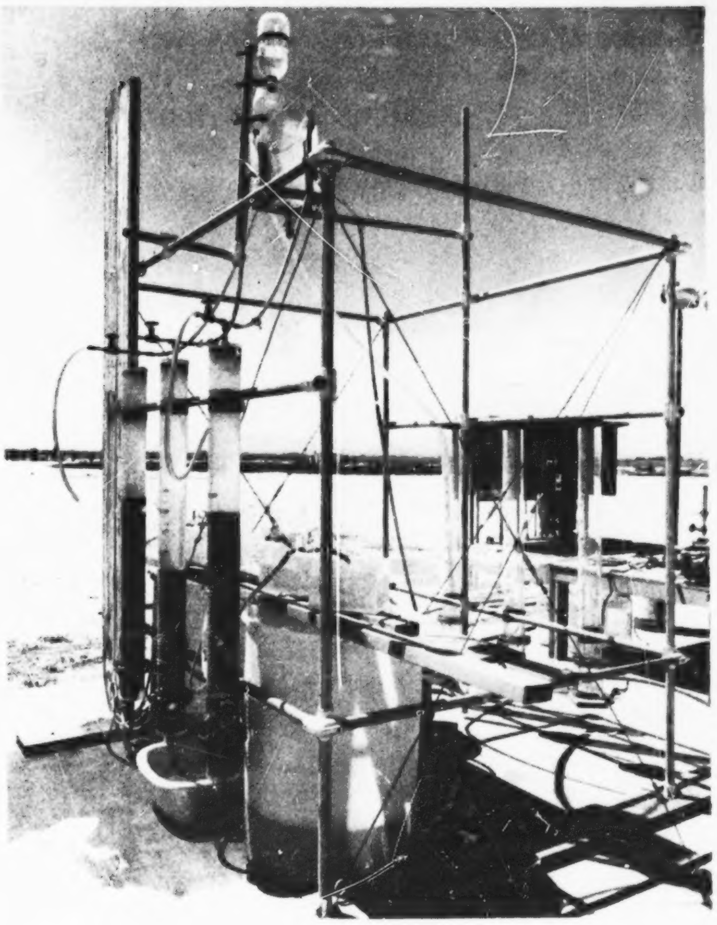
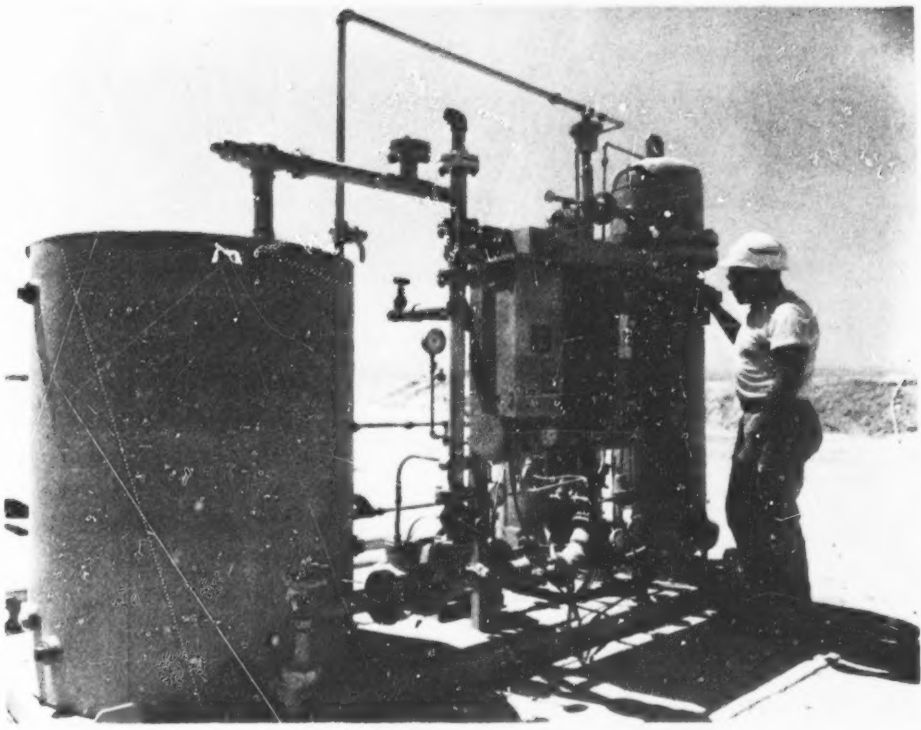
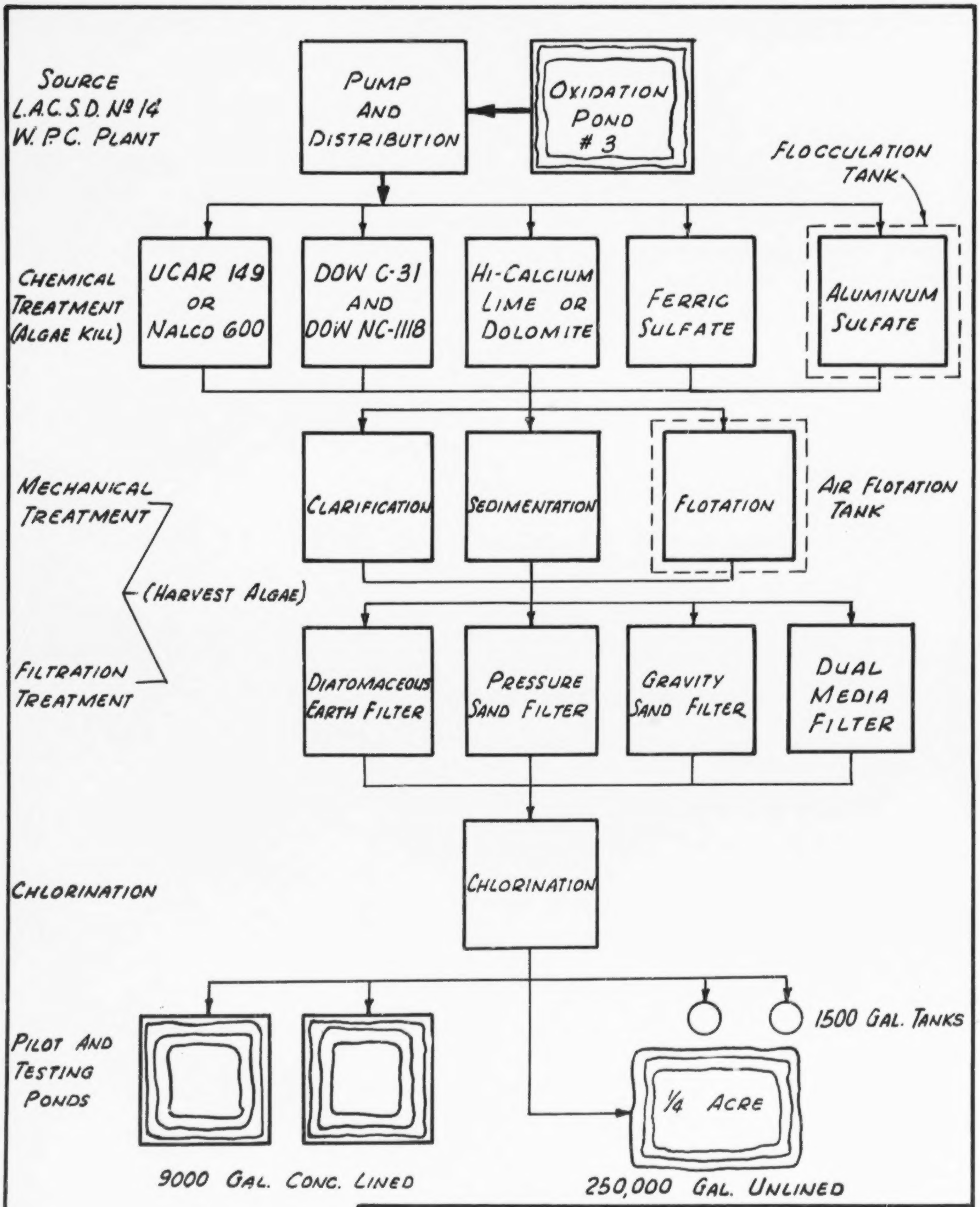


THREE AND ONE-HALF INCH
DIAMETER DUAL MEDIA
FILTER COLUMNS.

DIATOMACEOUS EARTH
FILTER UNIT.




SOURCE
L.A.C.S.D. Nº 14
W.P.C. PLANT
PUMP AND DISTRIBUTION
OXIDATION POND # 3
FLOCCULATION TANK
CHEMICAL TREATMENT (ALGAE KILL)
UCAR 149 OR NALCO 600
DOW C-31 AND DOW NC-1118
HI-CALCIUM LIME OR DOLOMITE
FERRIC SULFATE
ALUMINUM SULFATE
MECHANICAL TREATMENT
(HARVEST ALGAE)
FILTRATION TREATMENT
CLARIFICATION
SEDIMENTATION
FLOTATION
AIR FLOTATION TANK
DIATOMACEOUS EARTH FILTER
PRESSURE SAND FILTER
GRAVITY SAND FILTER
DUAL MEDIA FILTER
CHLORINATION
CHLORINATION
PILOT AND TESTING PONDS
1500 GAL. TANKS
1/4 ACRE
9000 GAL. CONC. LINED
250,000 GAL. UNLINED

DIAGRAMATIC LAYOUT
TERTIARY TREATMENT METHODS
U.S.P.H.S. GRANT W.P.D. 50-01 (R1)
DEPARTMENT OF COUNTY ENGINEER
COUNTY OF LOS ANGELES
JUNE 1965

PROCESS FLOW DIAGRAM

FLOW = 500,000 GALLONS PER DAY

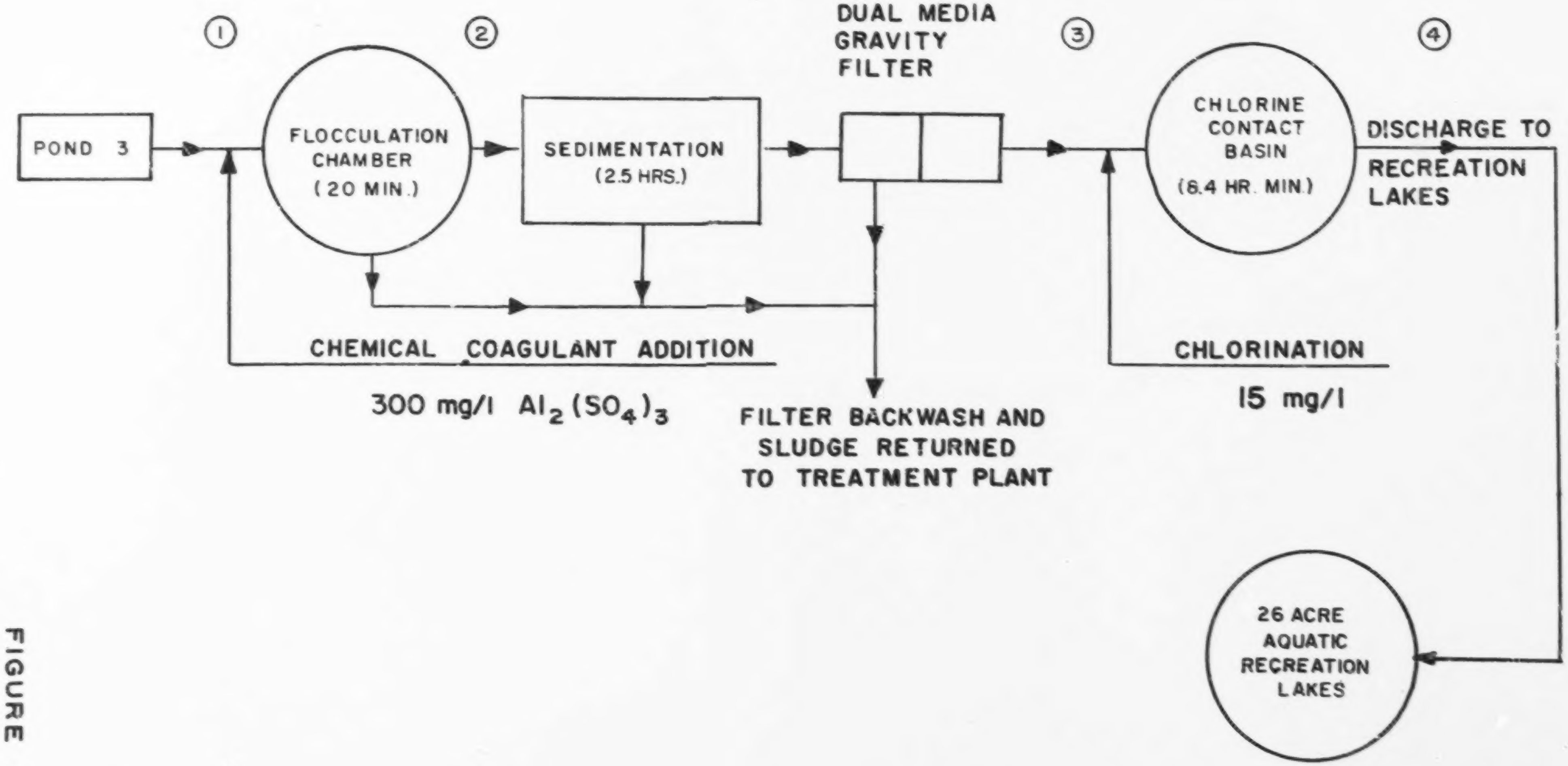

①
②
DUAL MEDIA
GRAVITY
FILTER
③
④
POND 3
FLOCCULATION CHAMBER (20 MIN.)
SEDIMENTATION (2.5 HRS.)
CHLORINE CONTACT BASIN (6.4 HR. MIN.)
DISCHARGE TO RECREATION LAKES
CHEMICAL COAGULANT ADDITION
300 mg/l $Al_2(SO_4)_3$
FILTER BACKWASH AND SLUDGE RETURNED TO TREATMENT PLANT
CHLORINATION
15 mg/l
26 ACRE AQUATIC RECREATION LAKES

FIGURE 6

TABLE 5

PROCESS WATER CHARACTERISTICS

	Pond 3 Water	Air Flotation Effluent	Sand Filter Effluent	Final Effluent
Sampling Station	①	②	③	④
p^H	8.3	6.8	6.8	6.8
Turbidity (J.T.U.)	90	15	8	6
Total Alkalinity (mg/l as $CaCO_3$)	260	140	140	140
Susp.Solids (mg/l)	75	25	12	10
Dissolved Solids (mg/l)	600	600	600	600
C.O.D. (mg/l)	190	90	75	75
B.O.D. (mg/l)	38	-	-	11
Hardness, (mg/l as $CaCO_3$)	80	85	90	90
Ammonia Nitrogen (mg/l as N)	0.1-20	0.1-20	0.1-20	0.1-20
Organic Nitrogen (mg/l as N)	7	3	2	2
Nitrate (mg/l as N)	1.0	1.0	1.0	1.0
Nitrite (mg/l as N)	0.1	0.1	0.1	0.1
Total Phosphate (mg/l as PO_4)	40	0.5-2	0.5 to 2	0.5 to 2
Carbon Dioxide (mg/l)	1	1	1	1
Dissolved Oxygen (mg/l)	0.5-35	7-15	7-15	7-15
ABS (mg/l)	5	5	5	5
Algae (counts/ml)	200,000	20,000	10,000	1,000
Coliform (MPN/100 ml)	150,000	10,000	10,000	0

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The tertiary treatment waste material which has been estimated as high as 15,000 to 30,000 gpd for a 0.5 mgd plant can be readily discharged to an oxidation pond downstream of the drawoff point. No interference is expected with the tertiary treatment process.

Cost estimates have been prepared for a 0.5 mgd and a 3.0 mgd facility for the preferred process. The summary shown on Table 6 is conservative, and it is anticipated that the water can be produced for less than the stated costs. A 0.5 mgd demonstration tertiary treatment facility, based on the preferred process has been designed and will soon be under construction.

F. PROBLEMS EXPERIENCED

The biggest problem encountered during the study of the various processes was the determination of the most satisfactory and economical treatment method. Considerable testing was performed before adoption of the preferred system.

Elimination of bacteria which use up dissolved oxygen became a problem. Studies to determine best removal were initiated. Low dissolved oxygen content in the final effluent, aggrevated by algal consumption, could be detrimental for use as lake water. It is expected, however, that sufficient algae removal can be attained.

It was found that regrowth of algae is a potential problem, since phosphate concentrations even as low as 1.0 mg/liter showed no significant inhibition to algae growth.

Disposing of the algae filtered from the treatment process could be bothersome. Dewatering, final drying and disposal are all difficult and expensive operations in this respect.

A satisfactory method of automatic controlling and metering for the tertiary treatment plant was found to be desirable. It will not be practical to have personnel on hand at all times for operation, maintenance and control.

As noted earlier, the chlorine residual of the treated effluent may be a cause of several fish deaths in the early experiments. A chlorine contact basin with a longer detention period and chlorination near the beginning of the treatment process was explored as a means of reducing the residual.

TABLE 6

SUMMARY OF ESTIMATED COSTS

Item	Plant Capacity	
	0.5 mgd	3.0 mgd
CAPITAL COSTS		
Total Capital Costs	$155,000	$387,000
OPERATION AND MAINTENANCE		
Chemicals (Aluminum Sulfate & Chlorine)	$ 69/mg	$ 69/mg
Power	8/mg	7/mg
Labor	46/mg	11/mg
Materials (O & M) Items	44/mg	19/mg
Sub-total	$167/mg	$106/mg
Contingency at 10% of Sub-total	17/mg	11/mg
TOTAL (O & M) UNIT COST	$184/mg	$117/mg
ANNUAL OPERATING AND MAINTENANCE COST	$34,000/yr	$128,000/yr
ESTIMATED COST PER AC-FT	$60 AC-FT	$38 AC-FT
ESTIMATED COST PER MILLION GALLONS	$184 M-G	$117 M-G

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Removal of nitrogenous compounds and synthetic detergents (ABS) in sufficient quantities appeared as a side affect problem. It must be determined if the present concentrations have any appreciable affect on algae growth, turbidity or fish life.

Ammonia concentrations showed a cyclical pattern, increasing from 3 mg/l in the winter to about 20 mg/l in the summer. The seasonal decrease of ammonia by biological synthesis accounts for the bulk of nitrogen removal in the oxidation ponds.

It should be noted that the longer the detention time in the oxidation ponds, the lower the ammonia content becomes. It is feasible that the pond discharge sequence may be rearranged to provide a significantly longer detention time. This technique should eliminate any problem of residual ammonia in the product water, thus relieving fish stress and odors, as well as reducing free nitrogen in the treated water.

PART III

PILOT LAKE LIMNOLOGY

A. OBJECTIVES

The second major program of the study was construction of pilot ponds. The small scale lakes were designed to simulate the final recreational lake environment.

During this phase of the research it was desired to evaluate the process water quality criteria, observe the chemical and biological behavior of the water, determine the tolerance of fish for the water, monitor algal growth, demonstrate adequate reduction of nutrient levels, and sustain water clarity.

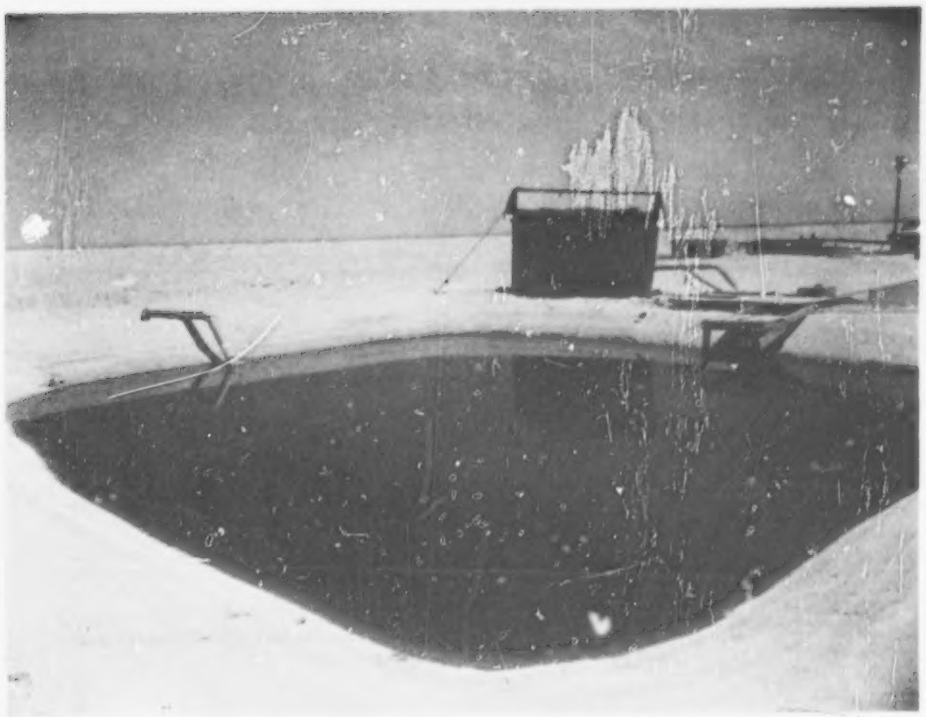
Since the reduction of phosphates in the treatment process was thought to be a major inhibitor to algal growth, the pilot ponds were also to be used to determine the relationship between phosphate concentration and algae regrowth.

B. PILOT POND FACILITIES

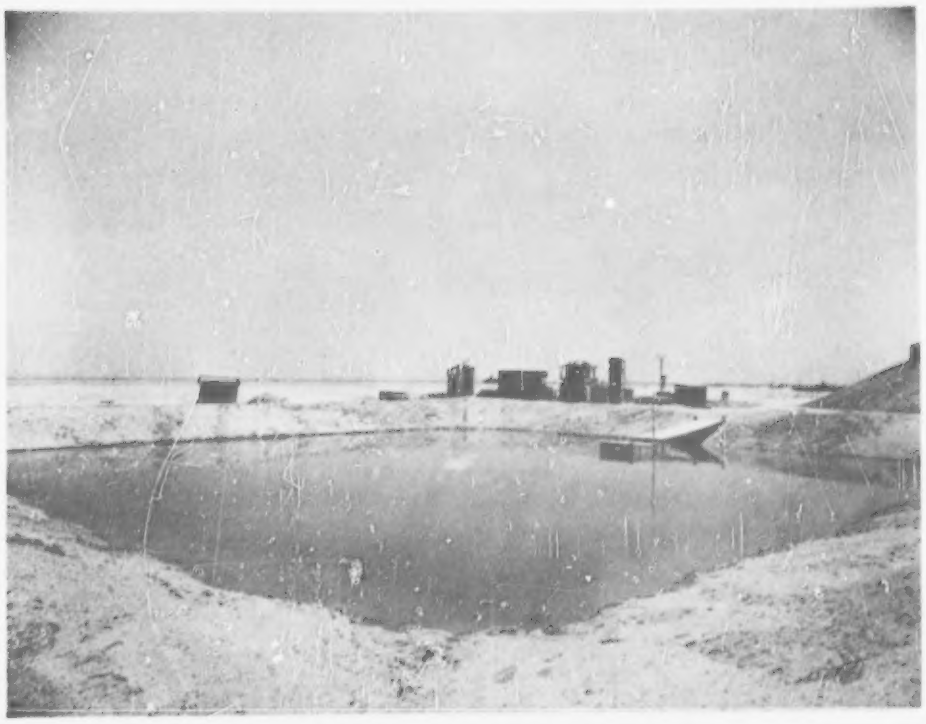
Two small 9000 gallon concrete-lined ponds and two 1500 gallon tanks were in operation for the preliminary testing. In June 1965, a 250,000 gallon dirt-lined, ten-foot deep simulated lake was constructed. This was done in order to approximate a more realistic facility comparable to the final proposed recreational lakes. Lake slopes will not require lining due to the high clay content of the natural soils. These soils form a tight barrier against lake water exfiltration. The pilot plant process was automated for continuous 24-hour operation and inlet flow of about 10 gpm. Evaluations made during this period include determination of algae regrowth potential, coliforms, viruses, and the suitability of various species of sport and other fishes.

Photographs of these facilities are shown on the next page.

Even though the research phase for development of a successful tertiary treatment process was concluded in June 1966, the basic pilot plant was retained for part-time use as a source of water for the simulated lakes and soil reclamation research needs.



9,000 GALLON CONCRETE-LINED BASIN
FILLED WITH TREATED WATER SINCE
1964 AND STOCKED WITH FISH IN 1965



250,000 GALLON EARTH-LINED
SIMULATED RECREATION LAKE
STOCKED WITH FISH IN 1965

The operation has been satisfactory even without the aid of laboratory controls in the later phase of the program. On several occasions equipment failure at the unattended pilot plant has resulted in the production of water somewhat higher in algae and residual phosphate than desired. In spite of these occurrences, water quality within the holding basins is considered equivalent to that in the basins during the initial program.

C. FISH STUDIES

Fish survival tests, using Bluegill (Helioperca incisor) and Channel Catfish (Ameiurus nebulosus) were conducted in both the 9,000 gallon and 250,000 gallon basins for many months, and results have been most satisfactory.

Twenty-five bass (Micropterus salmoides) and three Bluegill were placed in the earth-lined pond during August 1965. Fifty-five Bluegill and fifty catfish were added to the pond in October 1965. Seven hundred mosquito fish (Gambusia affinis) and twenty fathead minnows (Pimephales promelas) were added as food for the larger fish. Over 80% of the larger fish are still alive in the pond. Some fish were lost on four occasions due to problems encountered.

A fish died in November 1965 of skin infections apparently caused by a mechanical fish trap. No other deaths of this type have been observed since the termination of the trapping program.

Several fish died in early January 1966 as a result of chlorine residuals approaching 1.5 mg/l. The high chlorine residual resulted as the chlorine doses were increased from 8 mg/l to 15 mg/l. The ammonia concentration increased rapidly in December 1965 from a few parts per million to 23 mg/l and it was thought increased doses of chlorine would be required to maintain bacterial control. The extremely stable chloramines formed resulted in the chlorine residual approaching 1.5 mg/l and several fish died. Upon reduction of the chlorine dose, the chlorine residual dropped to a safe level.

At least 15 fish died in March 1966 as a result of an ammonia concentration of 8 mg/l. Rising water temperature and pH probably made the fish more susceptible to the ammonia. Half of the pond water was replaced with well water and no further fish deaths occurred. Storage of low ammonia content water in oxidation Pond 3 for use during the winter months when the normal effluent has a high ammonia content should eliminate this problem. During this month an additional forty bluegill and forty catfish were planted in the large basin.

During May 1966, an algae growth cycle caused the dissolved oxygen concentration to fall below 3.5 mg/l causing distress for some of the fish. Artificial aeration, by spraying some water into the air and diffusing air in the pond from a laboratory compressor, was started and the dissolved oxygen reached saturation in several days.

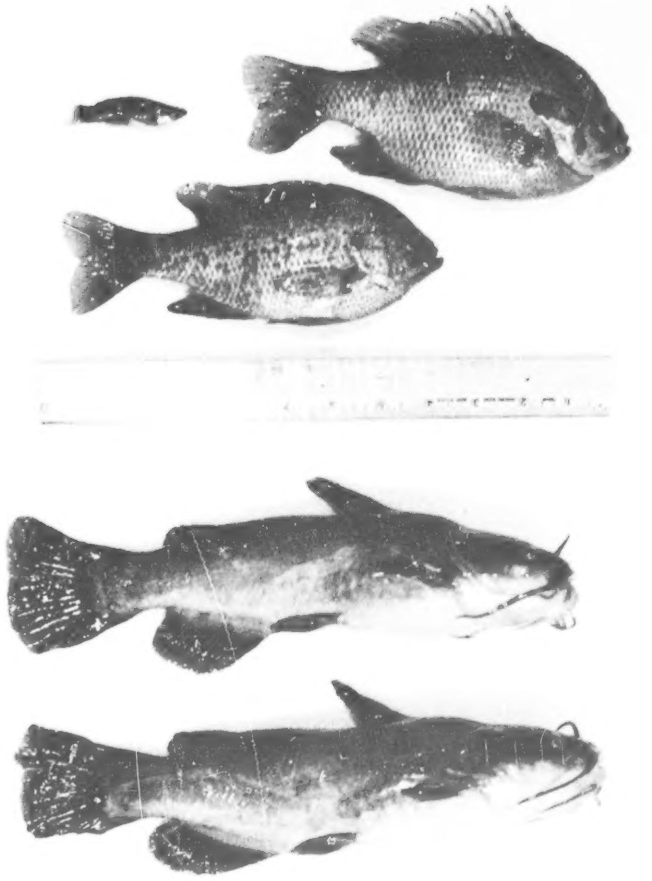
Although it has been impossible to inventory the fish population in the holding basins, it was apparent during the first year of operation that the Gambusia continued to spawn and one large catfish was captured during the raking of the grass from the lake. It appeared the catfish had at least doubled in length during its stay of little more than a year in the 250,000 gallon simulated lake.

During January 1968, extensive autopsies and biopsies were performed by a representative of the State Department of Fish and Game on fish netted from the test ponds. A check of water temperature on the day of the autopsies showed the pond water to be 5½ °C.

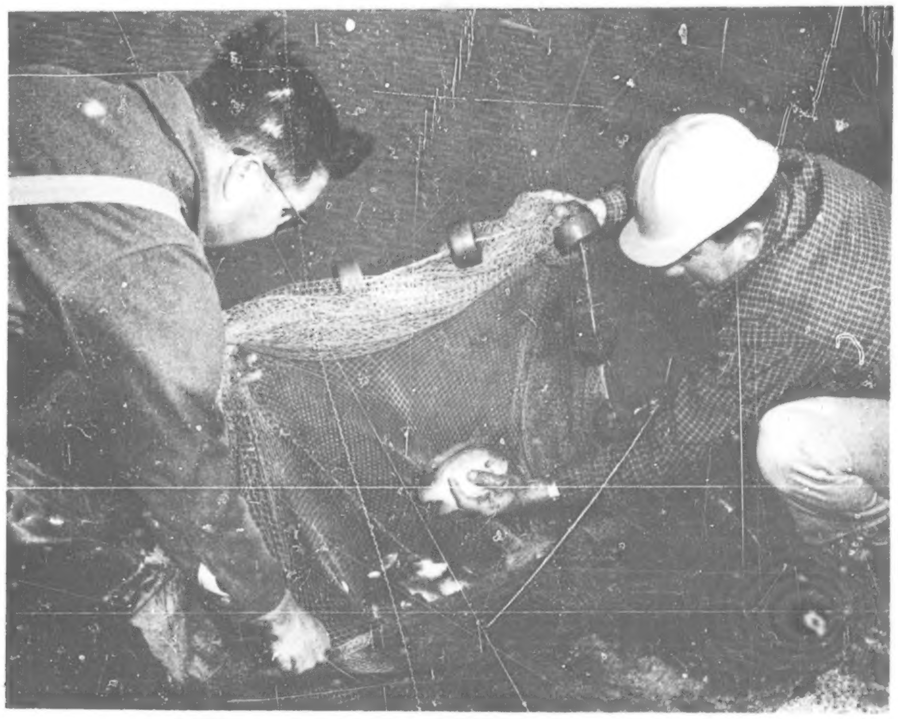
Tests performed on the fish included, among others, blood tests, dissection, a search of the stomach for cysts and worms, and a thorough inspection of the gills. During the examinations it was noted that roe were beginning to form for spring spawn.

Results of the tests showed that the fish are extremely healthy. The fish pathologist reports that both groups of fish examined were extremely free of parasitic organisims. A single specimen of Eustrongylides sp., the "red roundworm", was observed lightly encysted in the skin of a catfish and larval forms, Neascus of one of the strigeoid trematodes were noted in the liver of a single bluegill. It is generally agreed that the fish planted in the test ponds are as healthy and free of parasites as warm water fish in a natural stream.

During the netting operation, preparatory to the pathology studies, a very large number of small fry were caught. Successful propagation and very little parasitic infestation represent significant successes for the fish study program. Pictures of the netting operations and autopsy are included in the following pages.

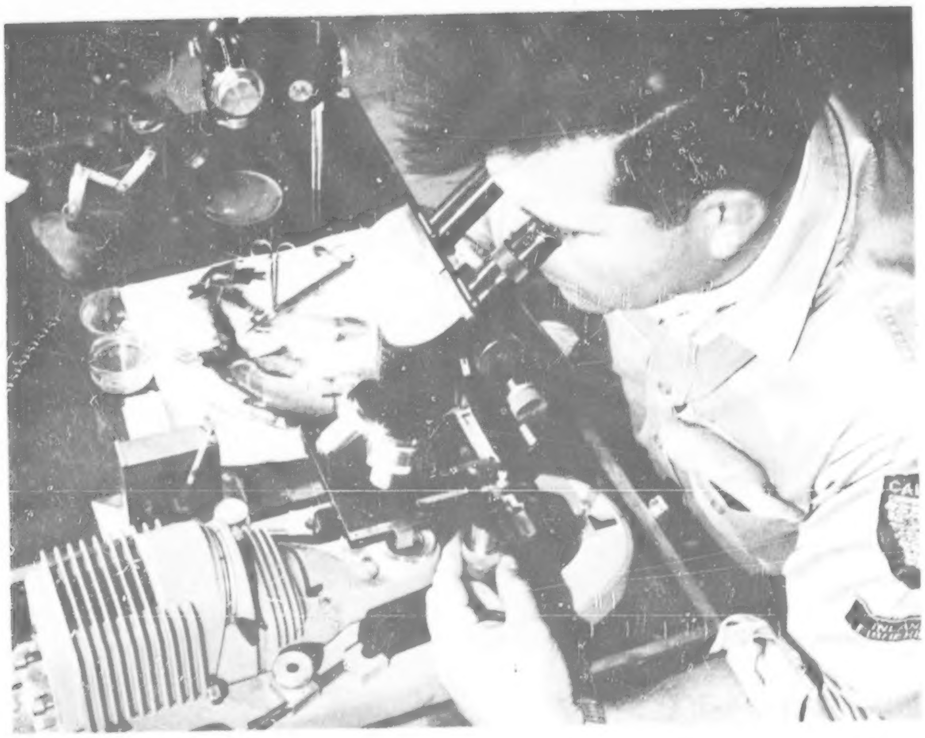


Examples of fish taken from pilot ponds after two years in simulated environment.



A sample of the bluegill fish taken from the test pond. Note the large number of fry.

One of many healthy catfish netted in pilot test pond.



Department of Fish and Game Fish Pathologist performing autopsy and biopsy studies on netted fish.

D. ALGAL GROWTH

Special laboratory studies have been conducted to determine if the reduction in phosphate by the pilot tertiary treatment plant is inhibiting the growth of algae. Samples of product water injected with varying concentrations of phosphate were exposed to continuous flourescent lighting and stirring. The study results indicated that phosphate concentrations below 0.5 mg/l would severly retard growth. Concentrations of 0.1 to 0.2 mg/l (normal concentration for the pilot plant effluent) inhibited growth very significantly. Complete growth inhibition would probably require removal of the phosphate levels well below the 0.5 mg/l level, but appears unnecessary at this time.

Pilot plant operation on a regular basis was discontinued during mid-1966. Make up water was added to the test ponds after that date only on an "as needed" basis. No laboratory control of the intermittant pilot plant operation was provided. Even so, test pond water quality has remained at an acceptable level. Table 7 below presents results of water analysis made during June 1967.

TABLE 7

250,000 GALLON SIMULATED LAKE

pH	9.8
Total solids, ppm	1,026
Suspended solids, ppm	81
Dissolved solids, ppm	945
Total phosphate, ppm PO_4	0.0
Dissolved oxygen, ppm O_2	9.7
Ammonia, ppm N	0.0
Nitrate nitrogen, ppm N	0.2
Nitrate nitrogen, ppm N	0.01

During the time the pilot treatment plant was under fully controlled, continuous operation, algae observations taken from the oxidation Pond 3 show the pond contains about 66 algae genera. Concentrations vary during the year with readings of 50,000 to 700,000 cts/ml. Scendesmus is the most common, although Euglenia, ankistrodesmus, Phacus, Oocystis, Orlorella, and Nitzschia have also been noted. Crustaceans most often found in the oxidation ponds, at random times, are Daphnia and Cyclops. These algae predators account in large part for the fluctuation in algae counts and algae genera.

The predominate free algae mass in the 250,000 gallon simulated pond is of the Nannchloris genera, an algae type seldom found in polluted waters.

Table 8 below is a comparison of certain major characteristics in the various test ponds. The Table reflects data taken during full time operation of the pilot treatment plant.

TABLE 8

COMPARISON OF WATER CHARACTERISTICS
IN HOLDING BASINS

Observation Period	Water Temp. (°C)	PH	Phosphate (mg/l)	Algae (Counts per ml.)	Predominant Algae Genera
10,000 GAL. BASIN					
Pilot Plant process evaluation Nov. 1964-June 1965	11	9.0	0.73	926	Closteridium and Scenedesmus
Continuous pilot plant evaluation Sept. 1965 - April 1966	13	8.9	0.12	247	Oscillatoria, Scenedesmus, Nitzschia, and Nannochloris coccoides
250,000 GAL. BASIN					
Sept. 1965 - April 1966	15	8.8	0.05	2400±	Nannochloris coccoides

E. ECOLOGICAL STUDY

Lake ecology will be a major contributor to the success or failure of the full scale project. With this in mind, the Los Angeles County Health Department initiated an ecological study of the pilot test ponds.

During the course of the study an effort was made to observe the various flora and fauna which developed in the ponds. In order to thoroughly study the ecological conditions present at the various times during the study, several techniques were utilized. Recordings were made of water and air temperatures, pH, dissolved oxygen content, and algae counts. Bottom sampling was done with the aid of an Eckman dredge in order to discover the benthos population, the species collected, and their relationship to the environment. Littoral and eulittoral samples were also taken where possible. A study of the wind and wave action was made to ascertain the influence, if any, on the biotic population and shore configuration. Any plants or animals taken by dredging or hand netting were subsequently identified in the laboratory. Particular attention was paid to the presence of midge (Chironomid) larvae and littoral vegetation, a source of potential mosquito breeding.

The study began January 11, 1968, when there was still ice on the pilot lake and was concluded April 4, 1968. An effort was also made to compare the pilot lake to existing lagoons between Avenue C & D, east of Division Street (Lancaster area). These lagoons impound the effluent from the oxidation ponds of the same water pollution control plant.

No samples were taken during the first visit of January 11, 1968, as there was still quite a bit of ice on the surface of the lake and some drifted snow on the ground. The second visit was made January 17, 1968, at which time samples were taken in different areas, and other conditions noted. Thereafter, weekly checks and investigations were made until the final visit of April 4, 1968.

The depth at the beginning of this study was approximately 10 feet. The ponds were subsequently filled to the maximum depth of approximately 11 feet, 6 inches, on February 10, 1968, when the treatment plant was in operation. Depth of water on April 4, 1968 was approximately 9 feet, 6 inches, a loss of 2 feet. This loss was a result of the fact that the plant was shut off after the pilot lake was filled and was subsequently not fully replenished.

The pH values fluctuated from 8.0 to almost 10 with an average of appriximately 9.0. Air temperature at the beginning of the investigation was 10°C. The bottom temperature rose from 6.1°C to 10°C. Surface temperature in all cases was 1.0 degree higher than the bottom temperature. In the middle zone, the temperature was 0.5 degree above the bottom temperature. The winds ranged from 0 to approximately 45 miles an hour at which time there were white caps on the oxidation ponds, and strong wave action in the lake.

At one time a severe windstorm blew dust into the pilot lake creating an opaque appearance in the water. The dust blown by the wind is so fine that it took quite a while to settle out on the bottom of the lake.

No readable amounts of chlorine were noted at any time during the course of the investigation.

Dissolved oxygen readings of 11.8 mg/l were made at the beginning of the study. Dissolved oxygen diminished to a low reading of 10.0 mg/l at the conclusion of the study.

The following animals were collected in the Eckman dredging samples: Cyclops spp. Amphipods (scuds) and Daphnia spp. The animals noted were abundant in the recovered silt. These little Crustaceans live just in or above the silt area, but are evident throughout the lake. They are an important part of the food chain in an aquatic environment of this type.

Many midges of the species Chironomus Walker (Chironomus Attenatus) were found in bottom and littoral samples, particularly in the areas where there was mud or muck which had been enriched with organic debris. No midges were observed on the northeast area of the pilot lake. The prevailing southwest wind develops a wave action which has scoured the littoral area in this section removing the silt and making the environment more or less untenable to the midges. An emergence of a few adult midges were noted on the surface of the water and on the shore at the last visit.

However, large adult midge swarms were observed hovering over the channels and lagoons in the vicinity of Avenues C and D, east of Division Street, where the effluent has only received secondary treatment.

Other varieties of aquatic fauna noted were the snail (Physa spp), and larvae of a small fly, Ceratopogonidae. The nuisance value or public health significance of these two species will have to be ascertained in the future.

Ephidrids (shore flies) were observed in the pilot lake. Shore flies remain in the immediate vicinity of the shoreline and have no nuisance value. It must be noted that a few of the areas were difficult to observe, as the footing in the mud was slippery and insecure, and the mud deep. It was also observed that bottom sampling in the littoral and benthic regions would create roiling conditions in the water which would take a long time to subside.

As noted above, there was a great deal of roiling each time an Eckman dredge sample was taken, both in shallow and deep water. Furthermore, the silt took a long time to settle due to the very small size of the clay particles. Also, as has been noted, it was difficult to walk in some areas of the lake along the shore because of sinking into the clayey mud. Further up the bank there is no problem, as the soil is well compacted.

It is possible that consideration should be given to stabilizing the area in the immediate vicinity of the shoreline. This would preclude creating an unsightly, messy condition, and will also limit or eliminate the growth of vegetation. This would also reduce erosion in those areas exposed to the fierce northerly winds which occur in the winter. It would appear that this treatment should not inhibit the growth or development of the fish plants. The total population would quickly stabilize itself to the amount of food and necessary shelter available.

The water appeared to be turbid throughout the course of the study. In some instances, this was influenced by algal blooms. No notice of lessening of the turbidity was found at any time, whether the weather was calm or blustery.

Even though a high degree of turbidity was observed in the pilot lakes throughout the course of the study, and relatively high pH readings were made, neither of these factors appeared to negatively influence the growth of the fish in the lake. Apparently those species of fish planted in the lake accommodated themselves readily to these conditions. This assumption is made because the fish which were netted by California Department of Fish and Game were existing satisfactorily in the test ponds.

The only species of vegetation noted during the study is the water grass, (Zannechellia spp.). The growth of small amounts of this grass was first noted March 8, 1968. Growth of the grass appeared to be heavier at each subsequent investigation. This is a particularly tenacious type of plant which grows rapidly, and mats readily. It forms small residual surface pools which are ideal environments for the breeding of mosquitoes. Other forms of vegetation which could conceivably emerge in an environment similar to the pilot lake are sedge, cattails, and rushes. All of these can provide excellent mosquito breeding conditions. They also bunch up or mat, thereby damming off the area to the entrance of mosquito fish, (Gambusia affinis).

Algae counts ranging from 37,000 to 42,000 per ml. were made. Most of the species appeared to be Phytoconis, Cladiphera, Tetradron. Several other species of algae were noted, but they were not in as great abundance as the three mentioned.

The biotic food chain, from algae to fish, appears to be well stabilized in the pilot lake. Again, reference is made to the quality of the fish taken by California Department of Fish and Game.

F. SIGNIFICANT PROBLEMS

The most significant problems encountered during the limnology investigation centered around the ecological aspects of the lakes.

The occasional strong winds have caused erosion of the unprotected slopes.

Certain types of weeds and reeds are capable of becoming breeding grounds for noxious insects.

The pilot ponds have exhibited considerable turbidity due to fine soil particles. The full scale facility is expected to be generally free of this problem since the lakes will be larger and deeper, the slopes will be planted, and trees will provide a partial windbreak.

Algae counts determined during the ecology study showed a significant algae population. It is well to note, however, that no new water had been added to the ponds, except as make-up water, for approximately one year prior to the study. During the time the pilot tertiary plant was operating, processed water algae counts were appreciably lower. (See Table 8.) This would indicate the need for continual monitoring of the full scale lake water as well as the need for addition of new processed water.

Each Eckman dredge sample yielded high populations of midges. How much of a problem they will become is conjectural. However, every effort will be made to limit the organic debris they need for survival. One suggestion would be to plant trees with heavy leaf drop back from the edge of the water. This would also do away with the oxygen demand that decomposition requires. Another would be to provide a berm or other structure that would not permit lawn runoff water to carry grass clippings or other organic materials into the lake.

PART IV

BACTERIOLOGICAL AND VIROLOGICAL STUDIES

A. OBJECTIVES

The importance of the coliform and virus sampling studies conducted by the Los Angeles County Health Department cannot be minimized. The primary objective of the research was to establish criteria for treatment of the waste water to assure a safe degree of enteric pathogen and virus destruction.

A secondary objective of the testing program was to aid establishment of general criteria for waste water reclamation and reuse. Other objectives of the studies were to chart the actual flow path and flow rates of the effluent through the oxidation ponds.

Throughout the testing program representatives of the County Health Department, the State Lahontan Regional Water Quality Control Board, and other State and local health officials met in an attempt to monitor progress of the tests and develop over-all criteria.

Minimum standards accepted at the start of testing were those indicated under Sections 7957 to 7960 of Title 17, California Administrative Code. At that time, Section 7958 required that coliform counts be less than 1000 per 100 ml. (MPN). Recent addition of Sections 8025 to 8050 to the code will insure that renovated waste water can be used without undue risk. Of particular note is the reduction of the permissible coliform count to less than 2.2 organisms per 100 ml. (MPN). Research data has shown that the adopted treatment process provides a product water which consistently exceeds the new requirements.

B. SAMPLING METHODS

The methods used for bacterial examinations were taken mainly from "Standard Methods for the Examination of Water, Sewage and Industrial Waste", Eleventh Edition, 1960, published by the American Public Health Association.

The basic laboratory methods were taken from "Procedure for the Isolation of Viruses from Sewage Effluent" obtained from the San Diego (California) Public Health Department.

Sampling Stations 1 through 7 were established for the main treatment plant and are shown on Figure 8. Sampling Stations 8 through 17 are located at different points of the pilot plant facilities as shown on Figure 9. These stations are described in Figure 7 on the next page.

"Grab" samples were taken at various points in the system and delivered the same day to the laboratory for bacteria estimations and identifications for coliforms, fecal coli and fecal streptococci. Also, "Swab" samples were delivered to the laboratory for virus isolation and identification. The latter swabs were allowed to stay in the waste water from five to seven days for adequate absorption in the cotton swabs in order to obtain a representative amount of viruses.

Sampling was done at weekly intervals. The bottles for bacteriological tests were prepared in the laboratory. A small amount of sodium thiosulfate was added in order to "inactivate" any possible chlorine that could be in the water at the sampling points.

C. BACTERIAL AND VIRAL ISOLATIONS

Both the bacteriological and virus samples were delivered to the Health Department laboratory in Los Angeles in metal containers containing ice. The bacteriological tests were set up the same day that the samples arrived. Similarly, "neutralization" of the swab samples was also carried out the day of arrival, and in most instances, centrifugation of the samples to concentrate the virus, separation of the latter from the bacteria, algae, organic matter, etc., was accomplished, with subsequent inoculation of the suspected virus-containing water in tissue culture tubes.

The bacteriological sampling was discontinued in November 1965, except for the withdrawal point in Pond No. 3. It was felt that sufficient data had been collected for the Health Department's purposes and further tests would not be required.

The results of the bacteriological tests conducted are shown in Table 9. It is well to note that the sampling program demonstrates a steady reduction of organisms as the treated water progressed through the system.

FIGURE 7

SAMPLING STATIONS

MAIN PLANT SAMPLING STATIONS (FIGURE 8)

Station Number	Description
1	Primary Sedimentation Tank Effluent (Raw sewage on the way to oxidation ponds)
2	Oxidation Pond 2 Effluent weir to Pond 4
3	Oxidation Pond 3 Effluent weir to Pond 5
4	Oxidation Pond 4 Effluent weir to Pond 3
5	Pilot Plant Intake Line in Pond 3
6	Oxidation Pond 1 Effluent weir to Pond 2
7	Oxidation Pond 1 Effluent weir to Pond 3

PILOT WORK AREA SAMPLING STATIONS (FIGURE 9)

Station Number	Description
8	Dissolved air flotation tank effluent
9	Dual media (anthracite-sand) gravity filter effluent
10	Two stage pressure sand filter effluent
11	Diatomaceous earth (D.E.) filter effluent
12	Holding Basin A Effluent (9,000 gallon concrete lined chlorine contact chamber)
13	Holding Basin B (9,000 gallon concrete lined product water holding basin)
14	Holding Basin C (1,500 gallon rubber tank for evaluating product water)
15	Holding Basin D (1,500 gallon rubber tank for evaluating product water)
16	Holding Basin E (250,000 gallon earth lined simulated lake for product water evaluation)
17	Pilot sedimentation tank effluent

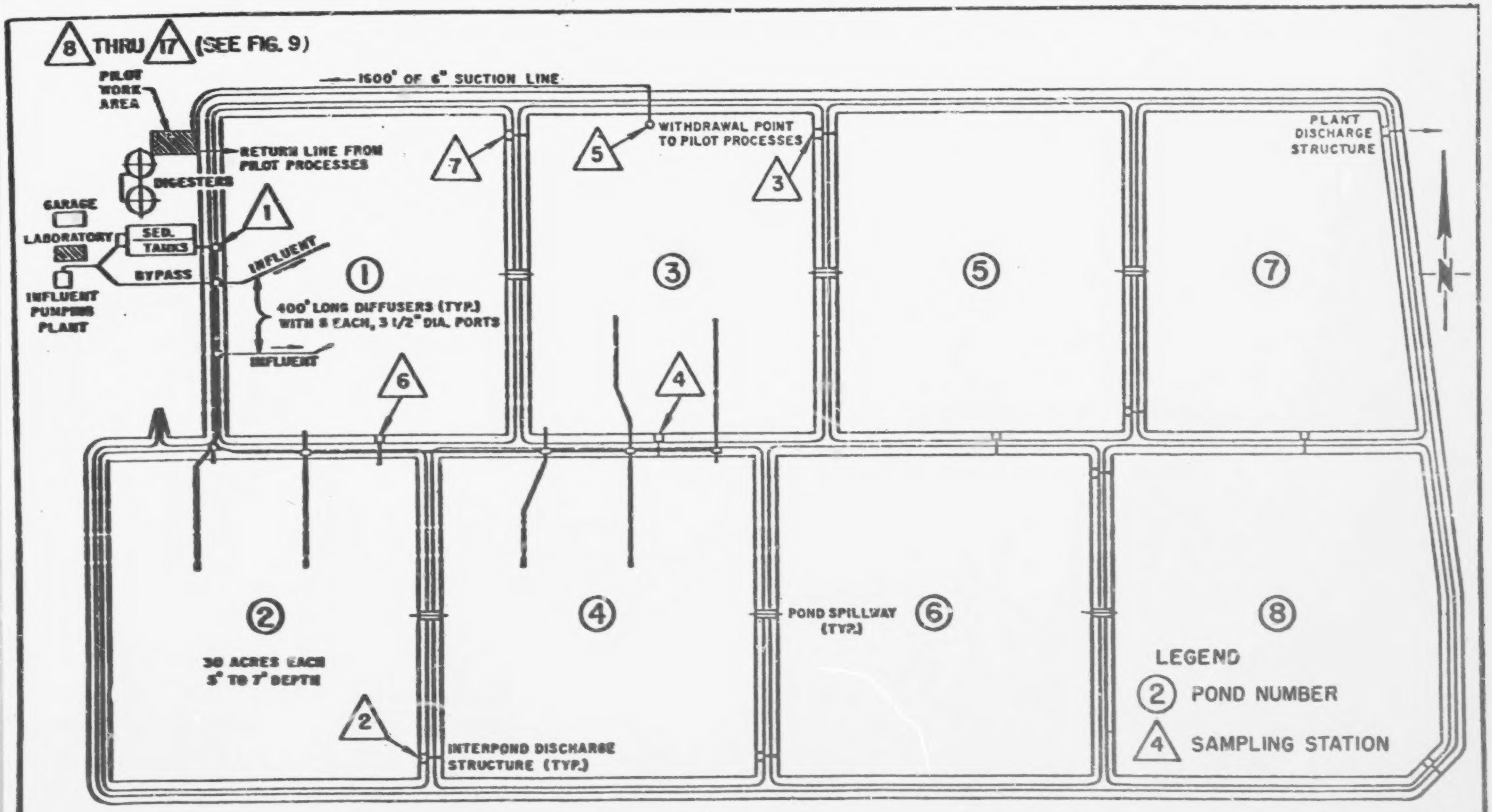

8 THRU 17 (SEE FIG. 9)
1600' OF 6" SUCTION LINE
PILOT WORK AREA
RETURN LINE FROM PILOT PROCESSES
DIGESTERS
GARAGE
LABORATORY
SED. TANKS
BYPASS
INFLUENT PUMPING PLANT
INFLUENT
400' LONG DIFFUSERS (TYP.) WITH 8 EACH, 3 1/2" DIA. PORTS
INFLUENT
WITHDRAWAL POINT TO PILOT PROCESSES
PLANT DISCHARGE STRUCTURE
N
1
2
3
4
5
6
7
8
30 ACRES EACH 5' TO 7' DEPTH
INTERPOND DISCHARGE STRUCTURE (TYP.)
POND SPILLWAY (TYP.)
LEGEND
2 POND NUMBER
4 SAMPLING STATION

FIGURE 8

DISTRICT 14 WATER POLLUTION CONTROL PLANT

LOCATIONS OF COLIFORM AND VIRUS SAMPLING STATIONS

SCALE 1" = 500'

PILOT WORK AREA SAMPLING STATIONS

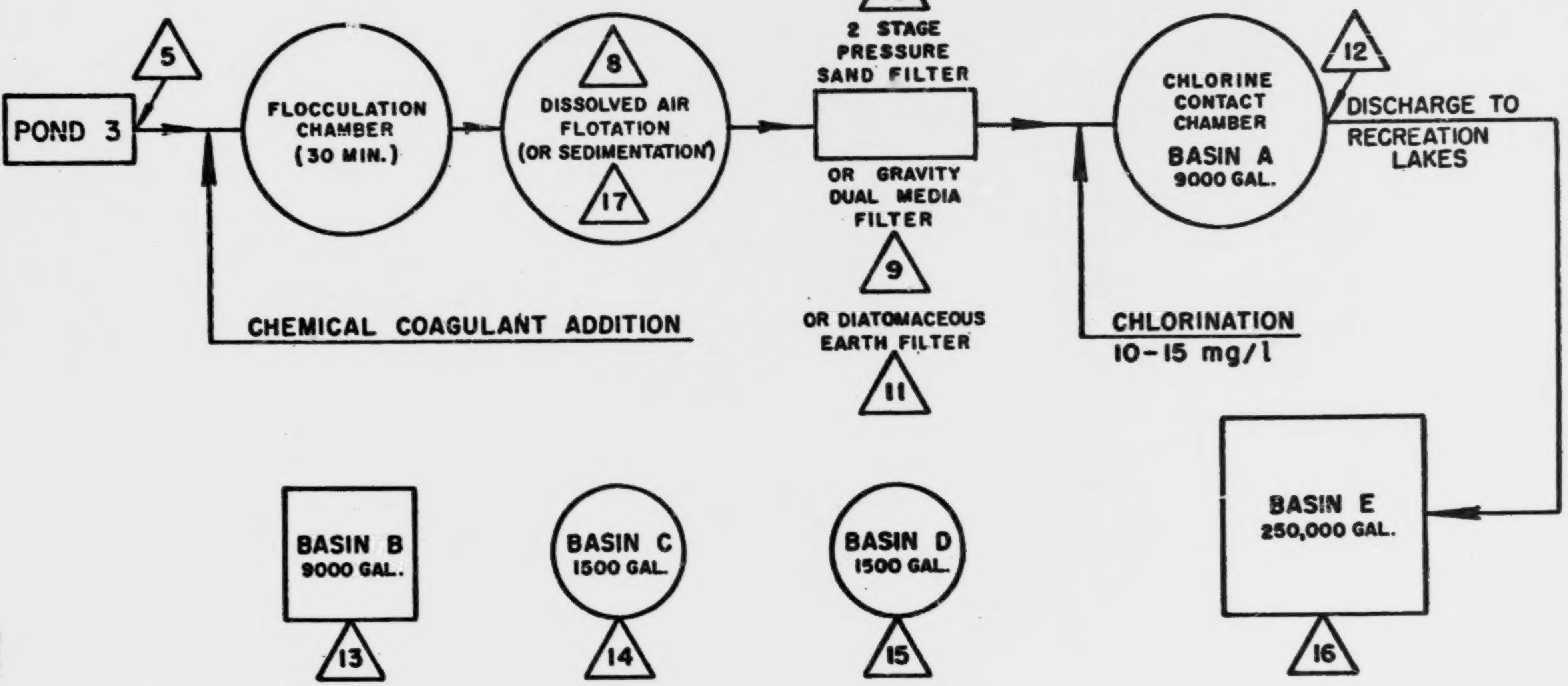

5
POND 3
FLOCCULATION CHAMBER (30 MIN.)
CHEMICAL COAGULANT ADDITION
8
DISSOLVED AIR FLOTATION (OR SEDIMENTATION)
17
10
2 STAGE PRESSURE SAND FILTER
OR GRAVITY DUAL MEDIA FILTER
9
OR DIATOMACEOUS EARTH FILTER
11
CHLORINATION 10-15 mg/l
CHLORINE CONTACT CHAMBER
BASIN A 9000 GAL.
12
DISCHARGE TO RECREATION LAKES
BASIN B 9000 GAL.
13
BASIN C 1500 GAL.
14
BASIN D 1500 GAL.
15
BASIN E 250,000 GAL.
16

FIGURE 9

TABLE 9

PAGE 1

MEDIAN READINGS OF WEEKLY BACTERIOLOGICAL TESTS FOR THREE MONTHS PERIOD (April through June, 1965)

Sampling Point	pH	MPN Brill Green Coliform/100 ml	MPN E.C. Broth Fecal Coli/100 ml	Millipore Filter Fecal Strep./100 ml
1. Primary Effluent	7.3	35,000,000	13,000,000	660,000
6. Pond #1	8.0	1,700,000	210,000	30,000
2. Pond #2	8.2	1,700,000	170,000	40,000
4. Pond #4	8.0	170,000	17,000	2,100
3. Pond #3	8.4	11,000	790	100
8. Air Flotation Effluent	6.7	3,300	less than 18	less than 100
9. Dual Media Filter	7.1	7,900	-*	-
13. Basin B	9.0	110	20	less than 100
14. Basin C	9.1	1,300	-	-
15. Basin D	9.2	20	-	-
16. Basin E	7.1	40	less than 18	less than 100

---

* "-" = No test done.

Prepared by County Health Department

TABLE 9

PAGE 2

MEDIAN READINGS OF WEEKLY BACTERIOLOGICAL TESTS JUNE TO DECEMBER, 1965

Sampling Points Arranged by Process Steps

Sampling Point	pH	Brill Green Coliform MPN/100 ml	E.C. Broth Fecal Col. MPN/100 ml	Millipore Strep/100 ml
1. Primary Effluent	7.4	70,000,000	14,000,000	505,000
6. Pond #1	8.3	2,000,000	230,000	16,000
2. Pond #2	8.1	1,100,000	280,000	15,500
4. Pond #4	8.3	79,000	16,000	420
3. Pond #3	8.6	4,100	640	39
5. *Withdrawal Point Pond #3	7.9	4,900	490	20
Pilot Plant Facilities				
8. Flocculation Chamber	6.6	450	180	80
17. Sediment Tank Effluent	6.7	230	20	10
9. Dual Media Filter Effluent	6.7	460	18	79
10. 2-Stage Pressure Sand Filter Effluent (Discontinued)	6.7	78	78	2
12. Chlorine Contact Chamber	6.8	1.8	1.8	2
13. 9,000 Gal.Concrete-Lined Pond	10.3	18	18	30
16. 250,00 Gal Unlined Pond	8.7	49	18	25

*Median values for entire year

Prepared by Los Angeles County Health Department

In order to concentrate existing virus particles present in the waste water, a prepared swab was tied securely at each sampling station and immersed in the flow for five to seven days. Each swab was then collected into properly labeled containers and transported to the laboratory under refrigeration, where it was immediately processed. Care was maintained at all times to avoid cross-contamination between specimens.

A study of the virus sampling program clearly indicates that as the effluent flows sequentially through the oxidation ponds, there is a steady die-off of the viruses which were found in 96% of the samples obtained at the discharge of the primary clarifier. The tabulation on the next page illustrates this decrease in positive samples as well as showing the types of viruses that were found at each station. It is noteworthy that Reo appears to be the most viable of the group. Review of data obtained indicates that the secondary treatment process is highly effective in the removal of viral contamination. Therefore, it is reasonable to conclude that this system, when coupled with a tertiary process of floculation, sedimentation, filtration, and chlorination will meet all of the requirements of interested health department officials concerned with maintaining general public health and well being.

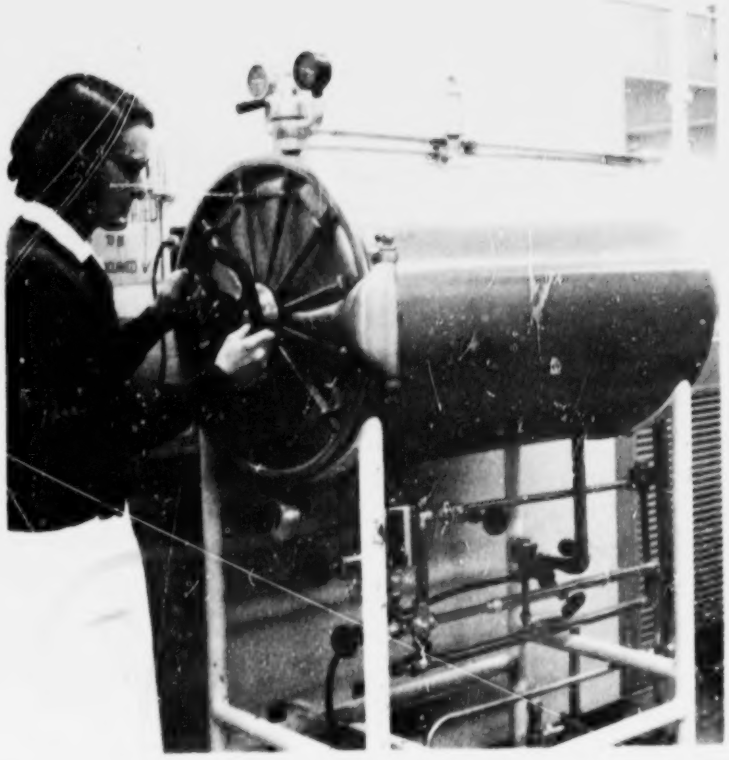
Pictures of the laboratory processes are included at the end of this section.

TABLE 10

TOTAL VIRUS ISOLATIONS

April 1965 through April 1968

	Polio I	Polio II	Polio III	Adeno	Reo	Cox B-3	Cox B-5	Echo 3	Echo 7	Echo 8	Echo 11	Echo 19 29	Unid	Total Spec.	Pos. Neg.	% Pos.	Total Isol.
Pond 1	32	56	26	59	41	2	5	1	10	2	1	1 Echo 19	1	96	93/3	96.9	237
Pond 2	2	5	24	21	0	1	0	2	0	0	0	0	0	65	37/28	56.9	58
Pond 4	0	2	0	6	6	0	0	0	0	0	0	1 Echo 29	1	66	13/53	19.7	16
Pond 3	0	1	0	0	3	0	0	0	0	0	0	0	0	80	4/76	5.0	4
Pond 6	0	0	0	1	0	0	0	0	0	0	0	0	0	14	1/13	7.1	1
Pond 7	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0/29	0	0

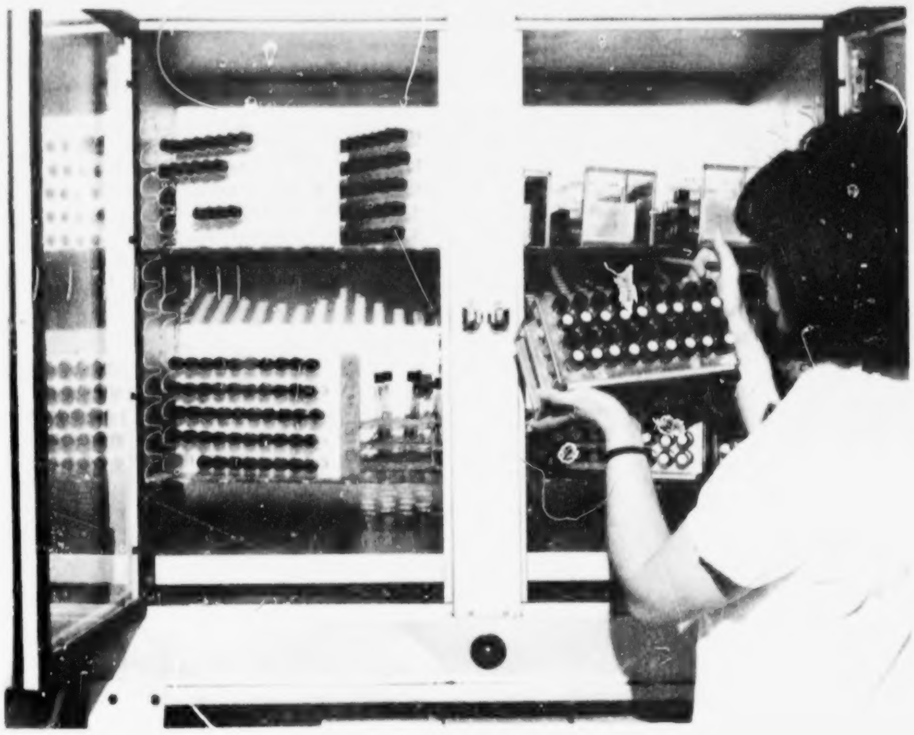


AUTOCLAVE USED FOR STERILIZATION
OF EQUIPMENT FOR BACTERIOLOGICAL
AND VIRUS STUDIES.

PREPARATION OF "SWAB" SPECIMEN
UNDER CONTROLLED CONDITIONS
FOR INITIAL CENTRIFUGATION.

ULTRA CENTRIFUGE SHOWING
ROTOR BEING SET IN PLACE,
10,000 AND 50,000 RPM.

FREEZER USED FOR STORING
VIRUS TISSUE CULTURES AND
SAMPLES AT -70°C.



INCUBATOR FOR TISSUE CULTURES.

MICROSCOPIC EXAMINATION OF TISSUE CULTURES FOR CYTOPATHOGENIC EFFECT.

D. RADIOACTIVE TRACER STUDY

As noted earlier, the County Health Department has conducted a virus survey on the oxidation ponds. The survey recorded progressive reduction in viable organisms through the pond system. In order to permit more positive interpretation of the virus findings it was desired to establish the hydraulic detention and mixing pattern through a radioactive tracer study. The study was prepared by a private consulting firm for the County Sanitation Districts.

The basic technique employed was to add a single charge of radioactive tracer to the sewer stream entering the pond system. Daily grab samples were subsequently taken at several points and their radioactivity was determined. The displacement of tracer through the series of ponds could thus be followed.

The pond layout, flow pattern, and sampling points are shown in Figure 10. Each pond is 30 acres in area and is about six feet deep. The flow pattern was identical to that which had prevailed during the virus sampling. The primary effluent flow of 3.2 MGD was split equally between Ponds 1 and 2. The effluent from Pond 1 discharged into Pond 2. Pond 2 delivered to Pond 4, and Pond 4 to Pond 3. Samples were taken from the outlet structures of these first four ponds. Weekly samples were also drawn from the primary effluent and from the plant discharge structure at Pond 7. The final effluent samples were taken as a monitoring precaution requested by the County Health Department, and were continued for four months from the date of tracer injection.

Sulfur-35 was used as the tracer isotope. Its 87-day half-life was large enough to permit detection throughout a two-month period of observation, but would assure essentially complete decay within two years. Non-radioactive sulfate is naturally present in the sewage in fairly high concentration, and participates to only a minor degree in chemical and biological reactions with the pond environment. The radioactive sulfate could thus be expected to follow faithfully the pond liquid in which it was dissolved. It was calculated that 700 millicuries would be sufficient to provide a reasonably precise picture of water movement through the first three or four ponds in the series. The material was purchased in the form of labeled sulfuric acid, dissolved in a few milliliters of hydrochloric acid solution.

To prepare for injection the source was submerged in a plastic drum containing about 20 gallons of acidified tap water. After removal of a sample for subsequent use as a standard, the radioactive liquid was siphoned into a drop structure downstream from the sedimentation tanks. The injection was spread out over about fifteen minutes as a precaution against the results being distorted by some transitory hydraulic effect. Grab samples were taken daily from each of the first four ponds for 35 days, and thereafter every two or three days. Pond sampling was discontinued 50 days after tracer introduction.

Samples were prepared for determination of Sulfur-35 radioactivity by first passing them through 0.45-micron Millipore filters. Fifty-milliliter portions were then evaporated nearly to dryness in beakers in a steam bath; they were transferred to 25-ml glass vials, evaporation was completed, and the residue was redissolved in one ml of distilled water. Radioactivity was determined in a Nuclear Chicago liquid scintillation counter using 15 ml of dioxane-base phosphor solution. The minimum counting time was 40 minutes. Initially the samples from Ponds 1 and 2 produced about 150 counts per minute in the instrument's Sulfur-35 energy channel. Instrument background count was about 20 cpm, and the final effluent samples (which were used as a reference background) ran about 35 cpm.

Figure 11 shows the results of all pond sample radioactivity determinations. A salient feature is the apparent speed with which the tracer distributed throughout the individual ponds. The material arrived at the outlets of Ponds 1 and 2 at maximum concentration in less than one day. In relation to the detention periods of these ponds (40 to 60 days), mixing was almost instantaneous. Also, tracer began to appear at the outlet of oxidation Pond 4 in low concentrations fairly soon, and in oxidation Pond 3 within a few days.

Theoretical curves based on perfect mixing have been given in Figure 11 for comparison purposes. Equations on the curves are as follows:

$$c_1 = c_2 = \frac{w}{2v} \quad e^{-t/2T}$$

$$c_4 = \frac{w}{v}(e^{-t/2T} - e^{-t/T})$$

$$c_3 = \frac{w}{v}\left[2e^{-t/2T} - e^{-t/T}(2+t/T)\right]$$

c_1 through c_4 = tracer concentrations at outlets of Ponds 1-4.

where

w = amount of tracer introduced
v = volume of single pond
t = time after injection
T = pond detention time (volume divided by plant flow)

The pond detention time T was taken at 15 days to fit the trajectory of the Pond 1 and 2 data. The detention period calculated on the basis of a 30-acre by 6-foot-deep pond and 3.2 MGD is 18 days. It may be noted that the measured concentrations in Ponds 4 and 3 were appreciably lower than the theoretical values, suggesting that some mechanism was operating to remove the tracer. The data shown in Figure 11 have been corrected for radioactive decay.

Tracer recovery as indicated by the initial concentration measured in Ponds 1 and 2 was quite satisfactory. The aliquot taken from the source before injection gave 1.2×10^{12} cpm as the total source strength. Using 115 cpm/50 ml as the starting concentration in Ponds 1 and 2, 30-acre pond area, and 6-foot pond depth, the recovered radioactivity was 1.0×10^{12} cpm. The difference can be attributed to reduced counting efficiency of the pond samples caused by the colored organic residue which remained in the samples after their evaporation. Recoveries could also be computed from the areas under the concentration curves (if the latter were complete); judging from the data up to 50 days the amount of tracer recovered would decrease progressively downstream.

On the day of injection (April 22, 1968) the rather strong breeze typical of the area had risen. The waves and surface currents which probably are the principal mixing mechanism may not be nearly as effective during calm weather.

The radioactivity of the final plant effluent in samples counted was as follows:

Sample Date	Plant Effluent Activity, cpm/50 ml
4-26-68	33
5- 3-68	32
5-10-68	31
5-17-68	34
5-24-68	34
5-31-68	37
6- 7-68	45

The June 7 sample had a 12-cpm increase over the normal background.

Assuming it was due to Sulfur-35 and allowing for 50 percent counting efficiency, the effluent could have contained 200 pc/L. The maximum permissible concentration for release to an uncontrolled environment (obtained by reducing the MPC in National Bureau of Standards Handbook No. 69 by a factor of 30) is 20,000 pc/L. Actually the 45 cpm on June 7 is probably a false reading.

The tracer results demonstrate that the oxidation ponds undergo complete mixing within a few days, at least during windy weather. Recovery of tracer was nearly complete in the first two ponds immediately after injection, but there was some loss or retarded appearance in the following two ponds. Tracer curves have shapes similar to theoretical ones based on perfect mixing. It is therefore possible for viruses to pass through the pond system in several days.

However, it is very important to note that a total of 237 viral isolations (96.9% of samples positive) were recorded at the Pond 1 viral sampling station. (See Table 10.) Moreover, only a total of four viral isolations (5.0% of samples positive) were determined at the outlet of Pond 3.

Even though it appears that viral short-circuiting is possible, the ponds are providing excellent and effective control of viral organisims. It is possible that the average hydraulic detention time is considerably longer than the tracer studies indicate. In addition, no positive correlation can be made between the quantity of virus present at the beginning of the oxidation pond series, the quantity of radioactive substance introduced at the same location and the subsequent measurements at the Pond 3 outlet. Decay rates of the isotope and death rates of the virus may vary considerably. It may be that a long detention time in an oxidation pond is not required for appreciable viral kills.

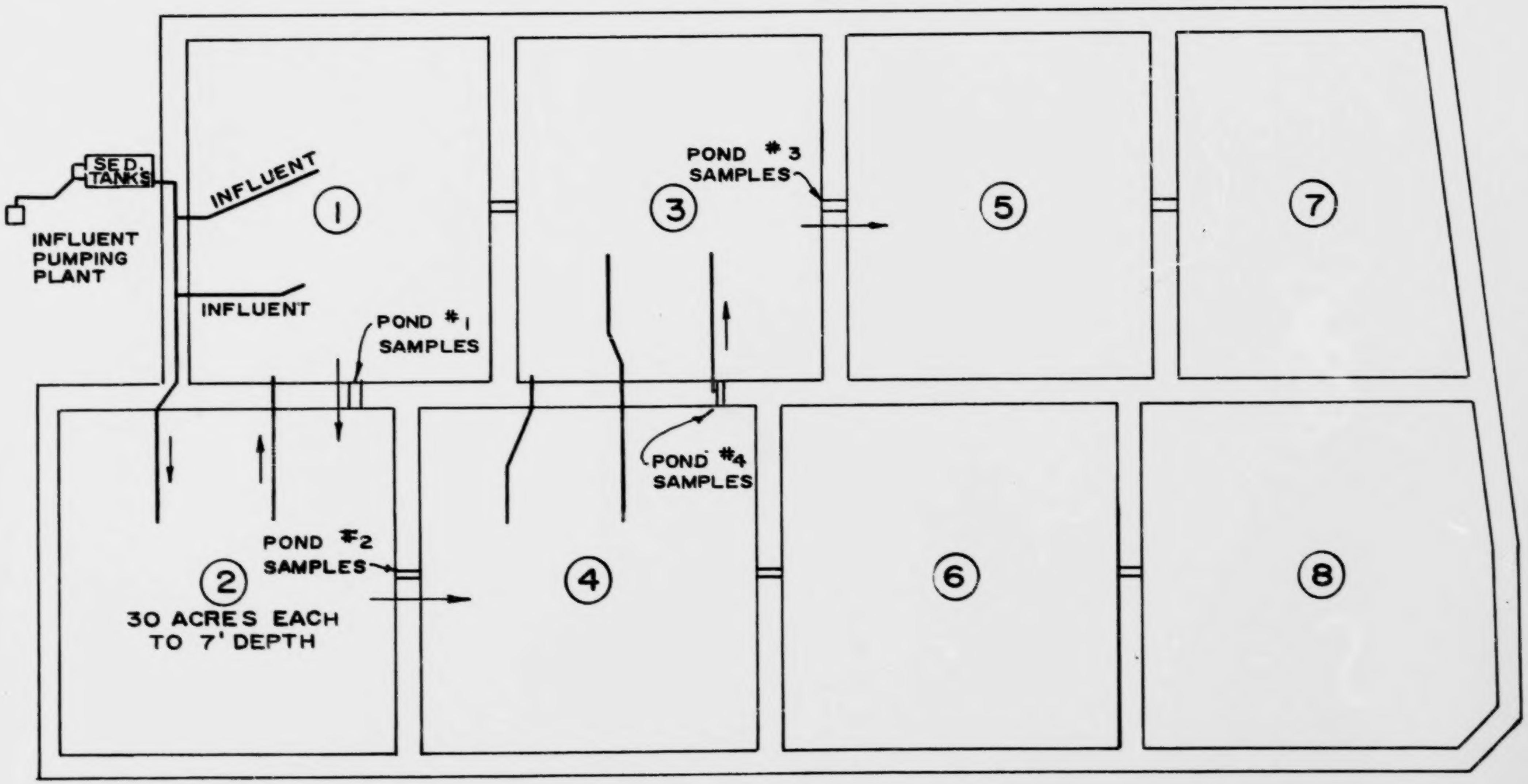
In any event, the flow rate through the oxidation ponds is apparently an important factor in the reduction of viruses and bacteriological organixms. Further study of the amount of detention time required for effective viral kill is indicated.

E. PROBLEMS EXPERIENCED

Problems encountered during the testing period stemmed mainly from inability to obtain satisfactory tissue cultures, and time lag between collection and testing. Tissue types used in the studies were African Green Monkey Kidney, Human Amnion, and Human Epidermoid Careinoma of Larynx (H.Ep #2). Readjustment of lab procedures and a change of tissue suppliers produced acceptable results.

Another problem, inherent in viral studies at this time, is the determination of all viral types and quantities present. It is anticipated that new testing procedures will be established in the future which will give more satisfactory results.

One important aspect of future work in this area will concern the establishment of a correlation between the results obtained from viral swab samples and bacteriological "grab" samples.


SE D. TANKS
INFLUENT PUMPING PLANT
INFLUENT
INFLUENT
POND #1 SAMPLES
POND #2 SAMPLES
POND #3 SAMPLES
POND #4 SAMPLES
①
②
③
④
⑤
⑥
⑦
⑧
30 ACRES EACH TO 7' DEPTH
N

POND LAYOUT AND SAMPLING POINTS

Scale 1" = 500'

FIGURE 10

TRACER RESULTS IN LANCASTER OXIDATION PONDS

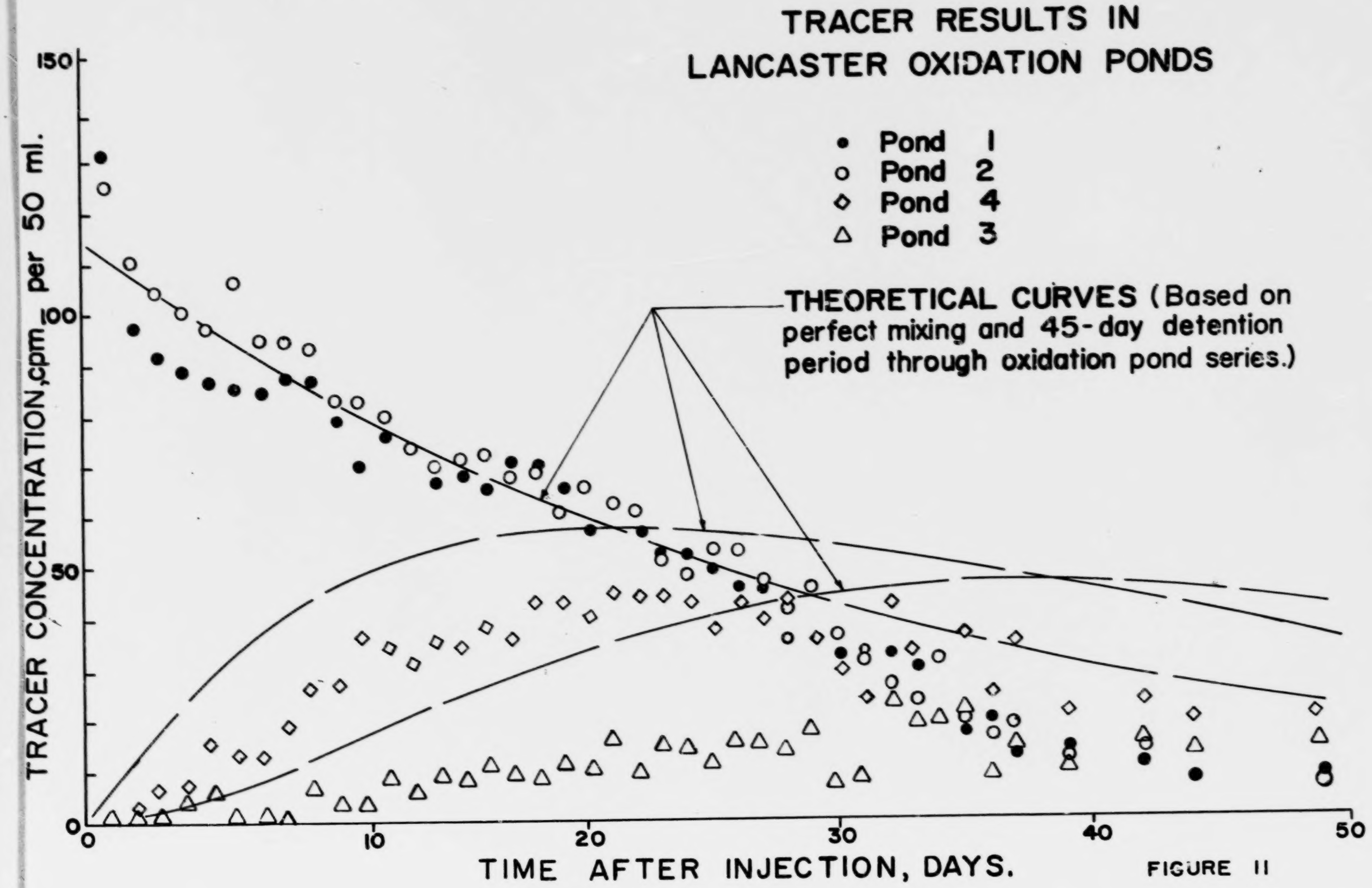


FIGURE 11

PART V

INDUSTRIAL USAGE STUDY

A. OBJECTIVES

There are many water associated processes used by industrial manufacturers that do not expressly require potable water. Conservation of natural and imported domestic supplies would indicate industrial application of renovated waste water. One aspect of the research program and pilot treatment plant was the determination of possible industrial uses for reclaimed water.

As in other phases of the research program, a lack of uniform agreement exists as to quality standards, applications, costs, etc. for waste water reuse.

The Industrial Waste Division of the Department of County Engineer was in charge of this research program.

A comprehensive approach was taken in this study to provide the useful data needed to determine which industrial processes can use reclaimed water. Various levels of water quality are available at the Antelope Valley Water Pollution Control Plant and all of these were considered for use. If the water quality requirements of the various industrial processes and operations can be established and the water quality available to the plant is known, it is a relatively simple task to determine if a particular industrial process can use the reclaimed water.

One phase of this study was to review all available literature on the subject of water quality requirements for various industrial operations and processes. To accomplish this goal an intensive program was initiated with correspondence being directed to manufacturing organizations, industrial groups, individual companies, professional societies, Federal and local governmental agencies and individuals concerned with or interested in water conservation and water reuse.

Another phase of the work included a major effort to contact all segments of industry throughout the nation. Letters with questionnaires were directed to all types of industries, manufacturer's organizations and other interested agencies. The letter briefly outlined our project and requested specific items of information on the quantity and quality of water required in their various processes and operations.

To supplement the data that is being received from correspondence, members of the Industrial Waste Division personnally met with the officials of industries located in the Los Angeles Area. These meetings were informal and provided an excellent opportunity to outline the project and its objectives. During these meetings management was asked for specific data about the quality of water necessary in their processes and operations.

A comprehensive sampling and chemical analysis program was initiated at the Water Pollution Control Plant in order to determine the quality of the reclaimed water in its various stages of treatment. It was anticipated that information gained from a complete chemical analysis would afford industry a sound basis on which to make their decision as to whether or not a particular process could use reclaimed water.

Data were compiled which tabulated the complete chemical analysis of the water furnished by the major water suppliers in the Los Angeles Area. This provided an indication of the quality of water being used in many varied industrial processes and operations. It also provided a comparison between the quality of water industry is currently using and that which would be available at the Water Pollution Control Plant.

B. WATER QUALITY

1. Review of Literature

An important phase of this study was an intensive review of the available literature in the fields of water reuse and water conservation. Scientific and technical publications were reviewed by the research staff. To supplement the information accumulated by the research staff, correspondence was directed to some research groups, industrial associations, selected manufacturing concerns, governmental offices and organizations and individuals concerned with water conservation and water reuse.

A number of replies indicated that the organization or individual did not have any data. Some replies have indicated that the letter of inquiry had been forwarded to qualified members for reply. It is anticipated that a portion of these will be returned with useful data. Other replies suggested that the staff contact other named individuals or groups.

The use of reclaimed water was presented in the following selected papers.

Abel Wolman reports an outstanding example of industrial use of sewage plant effluent is the Bethlehem Steel Company's Sparrows Point Plant in Maryland. In 1942, the steel mill first contracted to take 20 mgd of water from the Baltimore Sewage Treatment Plant. This proved to be a better supply than the saline Chesapeake Bay water or the available ground water supplies, which were increasing in salinity due to overdraft. The water is employed in the plant process for coke oven, blast furnace and open-hearth cooling; for cooling tower makeup, cooling rolling equipment, quenching coke and descaling operations. The alternate supply of ocean salt water was entirely unsuitable for rolling mill use due to the corrosive action of salt on the finished rolled surfaces. A separate industrial water distribution system was installed for the reclaimed water. Use of this reclaimed water conserved the available ground water to preserve its adequacy for sanitary and boiler feed water supply.

By 1960, the plant was using 110 mgd of treated effluent; this figure was expected to exceed 150 mgd and amounts to about 22 percent of the total plant requirement (650 mgd) of water.

* * *

N.T. Veatch refers to another example of industrial reuse which is that of the Cosden Oil and Chemical Company, Big Springs, Texas. Cosden was experiencing serious problems because of inadequate supplies of water, which were at best of poor quality. Full rights for water from the Big Springs contact aeration plant were consummated. Cosden's Refinery uses 1.215 mgd from the municipal sewage treatment plant flow of 2 mgd. The water is partially used as boiler feed and is of better quality than that of existing wells. The oil industry paid 90 percent of the cost of sewage disposal to the community in return for one-half of the water. The conventional sewage treatment facilities allow sufficient flexibility, so that by diversion and bypassing industrial wastes or other undesirable effluent, the reclaimed water can be maintained at reasonable mineral standards. In the next 10 years further needs are expected to increase. The reclaimed sewage effluent will be used for cooling purposes as well as boiler feed.

* * *

H.I. Riegel reviewed waste disposal operations at the Fontana Steel Plant in California. This plant is probably the only fully integrated steel plant not located on a large body of water from which water would be available as a source or outlet into which plant effluent might be discharged. Every operation is carried on to conserve water and control the pollution problem. In addition to intensive recirculation of water, a network of sanitary sewers covers the plant area. From the complete biofiltration sewage treatment plant the treated effluent is sent back to the industrial water system for further use. In 1952, the Kaiser Steel Company reused 141.5 mgd of 144 mgd available. Private communication received in May, 1966, indicated that 250 mgd were pumped for plant operations, of which 7.2 mgd represented make-up water.

* * *

J.F. Malina, Jr. described the operations at the El Paso Natural Gas Company Plant at Odessa, Texas, where the effluent of the Odessa Activated-Sludge Plant was used as a supply of treated waste water of excellent quality. They used the cold lime process to reduce phosphate concentration in the cooling water make-up; the hot-lime process and hot zeolite process to treat the boiler water; subsequent treatment of the waste water included cold-lime treatment in a solids contact unit, followed by recarbonation, pressure sand filtration, cation exchange units and blending. The quality of waste water is shown here:

	Treatment Plant Effluent	Cold Lime	Blend System
pH	7.0	10.5	6.1
Hardness (as $CaCO_3$) ppm	250	242	0
Calcium ppm	92	89	0
Chlorides ppm	177	175	175
Phosphates ppm	50	0	0
T. D. S. ppm	1310	1265	1016

M.C. Nichols reported on the major expansion of the Texaco Refinery at Amarillo in 1952, that they required at least 1.5 mgd water. For overall utilization of water it was decided to reclaim the once used city water for immediate and future needs. The result was a 4.5 mgd activated-sludge plant and a 9 mg effluent lagoon; a 10 mile transmission line and a 4.5 mgd pumping station. The refinery took 1.5 mgd. In 1961-62, the Amarillo Area Power Company of the Southwest Public Service Board took delivery of 1.5 mgd., with an increase to 2.5 mgd in 1964. The sewage treatment plant has been expanded to 9 mgd and a new 3.5 mgd expansion was undertaken.

The chemical work of the American Potash and Chemical Plant in Trona, California, for over 10 years, has used 3,500 gpm well water for cooling tower makeup supplied from brackish wells. The recirculated cooling water equals 75,000 gpm and has total dissolved solids as high as 33,500 ppm. Organic compounds are added to the cooling tower water and algae are present in the recirculated supply. Bromine treatment is used to control algae. The following is representative of the cooling water quality:

Alkalinity as $CaCO_3$	3,370 ppm
Carbonate	2,150
Chloride	15,460
Sulfate	5,680
Silica	1,012
Calcium	12
Magnesium	8.5
Total hardness as $CaCO_3$	70
Suspended Solids	25
Volatile and organic	658
pH	8.4

L.K. Cecil reported the Champlin Refining Company, Enid, Oklahoma, used local well water supplemented by a 250 gpm waste water recovery plant installed in 1931. After World War II a new sewage treatment plant was installed downstream from the refinery pump station. The refinery manager decided the straight sewage effluent was better than an alternate source consisting of effluent from the Enid Sewage Treatment Plant discharging to Boggy Creek about 1 mile away. The varying quality of Boggy Creek water appeared to be less desirable than that obtained from the direct line from the treatment plant.

In 1949, a smelter in a desert area wanted to use 0.5 mgd of effluent from a nearby Imhoff Tank-Dunbar bed sewage treatment plant for slag granulation. The odor in the produced steam was very bad. Installation of an Aero-Accelerator activated-sludge treatment unit reduced the 5 day BOD from 88 to 5 ppm, reducing the load on the Dunbar unit to give effective oxidation of ammonia to nitrate (0.15 and 39 ppm resp.). This resulted in no odor whatsoever even when the treated water flashed into steam at the slag granualtion pits.

Cooling tower makeup is normally required because approximately one percent of the circulating water is evaporated for each ten degree Fahrenheit cooling. In addition, most forced draft cooling towers lose between one-tenth and two-tenths percent of the circulating water because of windage. The cooling tower blowdown is employed to maintain dissolved solids below 2500 ppm; otherwise, considerable amounts of scale will occur. In general, when the mineral concentration reaches a maximum, depending upon the temperature and the processes involved, then cooling water blowdown must be resorted to, and a diluting makeup water is required.

The quantitative use of industrial water for boiler feed is smaller than other industrial uses. The type of boiler water treatment is dependent upon the pressure of the boiler. In general, however, it is desirable to have a low solids water with a minimum of silica. For most boiler feeds, water is frequently softened by means of a hot process, using dolomitic lime for removal of silica. This may or may not be followed by cation exchange softening or even complete demineralization. In general, organic waste waters would be difficult to demineralize or soften by the cation exchange process. At the Cosden Refinery, Big Springs, Texas, dolomitic lime and phosphate are added to decrease the hardness and control the silica reducing the dissolved solids. There is no difficulty in the operation of the boilers using sewage effluent from the City of Big Springs. Cosden's use of sewage effluent averages 1.215 mgd, of the 2 mgd flow which the sewage treatment plant receives.

C.H. Connell and M.C. Forbes present a table showing the increase in materials in sewage effluents over source waters:

Material	Range of Increase ppm
Magnesium	5-20
Calcium	10-50
Ammonia	2-20
Silica	10-20
Phosphate	10-50
Nitrate	1-20
Chloride	25-125
Sulfate	10-40
Alkalinity	30-100
Total dissolved solids	150-500

A table listing various industrial usages of sewage effluent is shown at the end of this section.

J.H. Feth gives some values for the normal range of mineral pickup due to use of water for domestic purpose:

Dissolved solids	100-300
Boron	0.1
Sodium	40-70
Chloride	20-50
Potassium	7-15
Alkalinity	100-150
Magnesium	3-6
Calcium	1-16
Total nitrogen	20-40
Sulphate	15-30

2. Industrial Water Quality Requirements

A roster of the industrial organizations who are members of the National Industrial Council was used as a guide to compile a list of manufacturing associations. The associations selected were those which use significant amounts of water in their operations. Food processing industries, even though they use large amounts of water, were not considered in this study. This is essentially because of the human aversion to the thought of consuming food which has been processed with reclaimed sewage effluent. The Health Department has conducted Bacteriological and Virology studies on the reclaimed water. (PART IV)

Letters were mailed to the selected manufacturing associations as a part of the effort to determine the quality of water that is required in their industrial operations and processes. These letters briefly outline the water reclamation project and requested their participation by completing a questionnaire. The questionnaire included with the letter covered such specific items as the maximum quantity of chemical constituents which could appear in the source water and not affect the quality of their product or interfere with operations.

Most of the associations who replied to our inquiry have little or no information on the subject. A few have forwarded the letter of inquiry to their technical staff for processing and reply. Some of the organizations have indicated that it would be necessary to contact their membership directly for data of such a technical nature.

An example of a positive response is that of the Can Manufacturer's Institute, Inc., which also suggested contacting its membership for the technical data required in the questionnaire. A portion of their reply stated the following:

> "For process cooling, in which the cooling water does not contact the can parts or "raw materials" we see no reason why reclaimed water could not be used if it were readily available to the plant. In most instances much of this water is recirculated, so that overall consumption is not significantly high.
>
> The same applies for hot water space-heating systems--the water is recirculated and we see no reason why reclaimed water could not be used for this except the consumption is small. For use in steam generation the respective plant engineers would object strongly to use of reclaimed water--it could be used with proper additives or water treatment at the local plant, but the composition of the water would need to be constant.
>
> For water-wash exhaust air systems, such as for removing particulates or overspray from the ventilation exhaust air at can-spraying operations, the consumption rate of water is also comparatively low since most of such water is recirculated--only a small amount of fresh water is constantly added. But certainly reclaimed water could be used for this purpose if it were readily available."

The Industrial Waste Division is currently inspecting over 2300 industrial and commercial installations whose operations produce a variety of industrial wastes. The installations include oil refineries, aircraft and missile plants, manufacturing plants and plating and metal finishing plants These are located in the unincorporated territory of Los Angeles County and in 27 cities which have contracted with the County Engineer for Industrial Waste Inspection Services.

The Industrial Waste Division staff personally contacted industries throughout the Los Angeles Area and requested their participation in the study. They were asked to complete a questionnaire which would indicate the quality of water needed for thir operations. Copies of the completed questionnaire are shown at the end of this section.

Most of the plants in the Los Angeles Area use the potable water furnished by local water agencies. Because these water supplies are of good quality it is used without pretreatment of any kind. At the present time they have not established a minimum quality of water which can be safely used in their operations.

A large aluminum anodizing firm contacted fabricates and anodizes large architectual panels. The anodizing operations require 14 tanks which hold solutions for the various colors needed in the final product. These tanks range in capacity from 5,760 gallons to 10,560 gallons. The water supply to this company has a total dissolved solids concentration of 780 parts per million. In addition to its normal water demand the company uses an additional 10,000 gallons of demineralized water each day.

Management of this firm indicated that if the total dissolved solids concentration in the source water should exceed 1,000 ppm the quality of the finished product would be affected. Also chloride content in excess of 20 parts per million and iron in any concentration interfered with the quality of the anodized finish.

A company which does enameling on steel and aluminum panels was also contacted for its water quality requirements. This plant incorporates a pickling room in the production line. For steel pickling operations a total of ten 2,000 gallon tanks are used. Aluminum surfacing operations are performed in a separate series of seven 2,000 gallon tanks.

This company uses approximately 300,000 cubic feet of water each month. Experience in the plant has shown that high concentrations of calcium in the rinse water reduces the effectiveness of the coating and produces streaks in the color of the finish on aluminum panels. Traces of iron in the water will cause difficulties with the color of the finished coating on aluminum panels. High sulfates, carbonaceous residue and siliceous material are undesirable.

Contact was also made with a concern which manufactures complete systems for producing steam for use in oil field thermal recovery operations. The steam is injected into oil wells as part of a program for increased production.

The quality of the water required for use in the steam injection systems were reviewed. The hardness that can be handled in these units is not limited. Hardness does affect the duration of the service cycle and the frequency of regeneration. The source water must be free of oil and must not contain a sodium content which is more than about 85% of the total cations expressed in parts per million equivalent of $CaCO_3$. The sodium content should not be more than 5.5 times the total hardness. Excess sodium necessitates down rating the exchange capacity of the softeners.

Aeration, filtration and chemical treatment as required are functions usually performed on the job site by the water user.

Two sample responses to the Division's questionnaire follow.

COUNTY OF LOS ANGELES
DEPARTMENT OF COUNTY ENGINEER
INDUSTRIAL WASTE DIVISION
108 W. 2nd Street
Los Angeles, California 90012

INDUSTRIAL WATER USE SURVEY

Name of Company ____

Address ____

Chief Products Printing & Business Grade Paper & Napkins

Type of Operation Operation starts with dry pulp. Pulp is mixed with water, then formed into sheets on screen conveyor, dried, rolled & then cut to size, clay is used as filler.

Processes ____

Fresh Water Supplier Metropolitan, City and Own Well

Total plant fresh water consumption *1,500,000 Per 24 hours

Total plant brackish water consumption ____ Per ____

Quantity of softened water used ____ Per ____

Quantity of deionized water used ____ Per ____

*Water used in pulping & sheet forming is recirculated 15 times before being discharged to sewer.

ESTIMATED WATER USAGE IN THE FOLLOWING PROCESSES

Washing ____	Floor & Equipment Washdown 139,550 gpd
Rinsing ____	Boiler Makeup 3,000 gph
Solutions ____	Other Pulping & Paper Sheet Forming (1,255,950 gpd)
Cooling Tower Makeup ____	____

ESTIMATED QUANTITY OF INDUSTRIAL WASTE WATER DISCHARGE

To Sewer Dry Weather - All Per ____

To Surface Wet Weather - All Per ____

Ind. Waste water to San Jose Wash during rain.

To Cesspools, drywells, leaching lines ____ Per ____

INDUSTRIAL WATER USE SURVEY (cont'd)

CONSTITUENTS WHICH MIGHT APPEAR IN WATER THAT WOULD AFFECT QUALITY OF PRODUCT OR INCREASE OPERATING COSTS.

Constituent	Process Affected	Max. Acceptable Conc. (ppm)
Calcium	All paper making	200
Sodium	"	?
Iron	"	Very little
Bicarbonate	?	?
Chloride	"	1.5
Sulfate	"	200
Phosphate	?	?
Hardness (as $CaCO_3$)	"	200
Silica	"	Very little
Total Dissolved Solids	"	500
Oil and Grease	"	None
Turbidity	"	None
Boron		
pH	"	7. to 7.6
Nitrate		
Algae		
Organic Material		
B.O.D.		
Other		

Date Form Completed____________________

COUNTY OF LOS ANGELES
DEPARTMENT OF COUNTY ENGINEER
INDUSTRIAL WASTE DIVISION
108 W. 2nd Street
Los Angeles, California 90012

INDUSTRIAL WATER USE SURVEY

Name of Company __________

Address __________

Chief Products Leather

Type of Operation Tanning

Processes Washing, Chrome tanning, Dying, Fat Liquoring, Finishing

Fresh Water Supplier California Water Service

Total plant fresh water consumption 293,800 cu.ft. Month
2,203,500 gal Per Month

Total plant brackish water consumption _____ Per _____

Quantity of softened water used None Per _____

Quantity of deionized water used None Per _____

ESTIMATED WATER USAGE IN THE FOLLOWING PROCESSES

Washing 1,671,500 gpm

Floor & Equipment Washdown _____

Rinsing _____

Boiler Makeup _____

Solutions _____

Other Plant Maintenance 2,000 gpm

Cooling Tower Makeup _____

ESTIMATED QUANTITY OF INDUSTRIAL WASTE WATER DISCHARGE

To Sewer 2,203,500 Per Month

To Surface _____ Per _____

To Cesspools, drywells, leaching lines _____ Per _____

INDUSTRIAL WATER USE SURVEY (cont'd)

CONSTITUENTS WHICH MIGHT APPEAR IN WATER THAT WOULD AFFECT QUALITY OF PRODUCT OR INCREASE OPERATING COSTS.

Constituents	Process Affected	Max. Acceptable Conc. (ppm)
Calcium	Dying	33 ppm
Sodium		
Iron	Tanning	.1 ppm
Bicarbonate		
Chloride		11 ppm
Sulfate		79 ppm
Phosphate		
Hardness (as $CaCO_3$)	Dying	116 ppm
Silica	Tanning	8 ppm
Total Dissolved Solids	Dying	148 ppm
Oil and Grease		0.0 ppm
Turbidity		
Boron		
pH	Tanning & Dying	7.5 ppm
Nitrate		
Algae		
Organic Material		
B.O.D.		
Other		

Date Form Completed ______________________________

TABLE 11. SUGGESTED LIMITS FOR BOILER FEED WATER

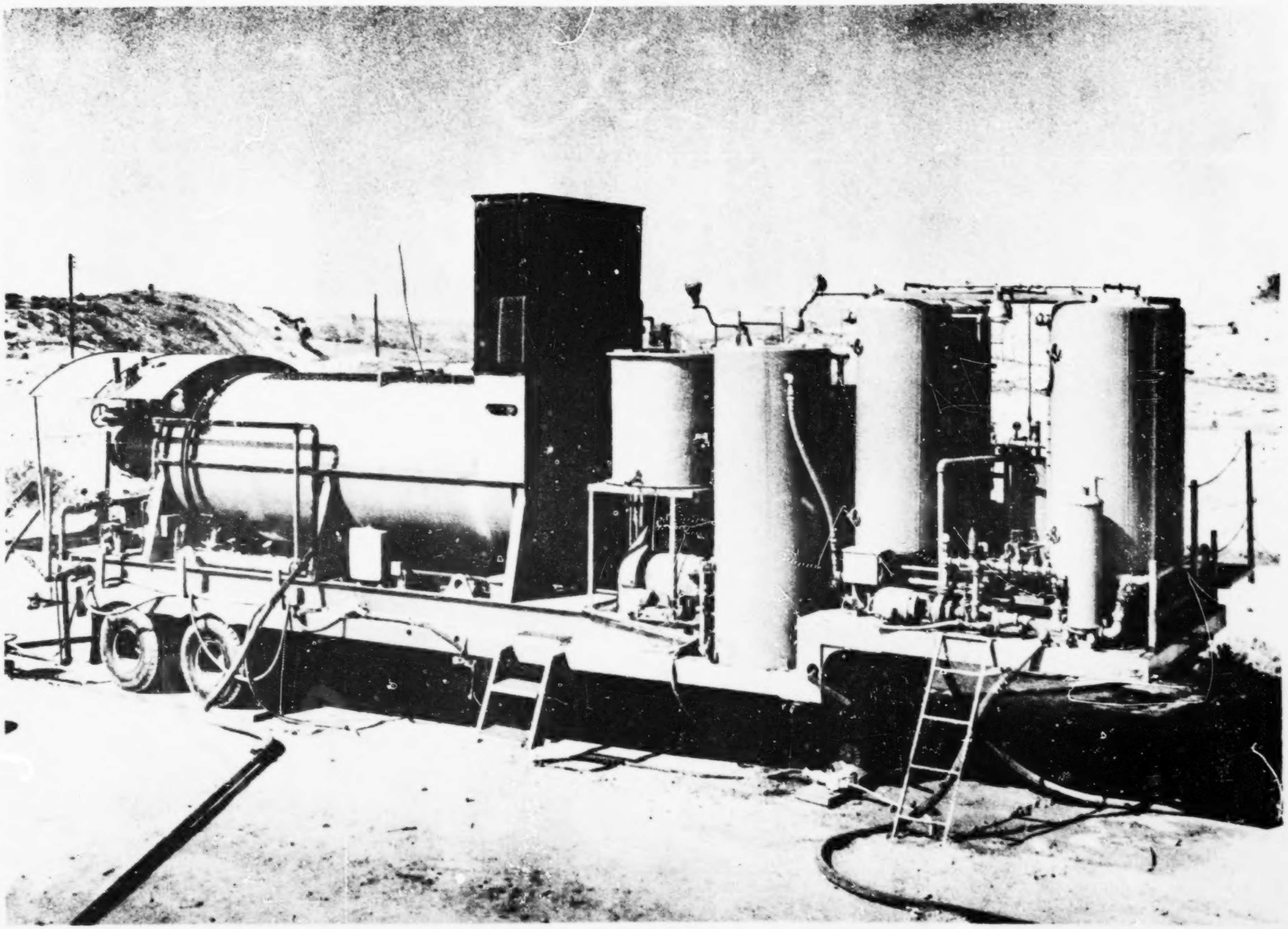
	Pressure (psi)			
	0-150	150-250	250-400	Over 400
Turbidity, units	20	10	5	1
Color, units	80	40	5	2
Oxygen consumed, ppm	15	10	4	3
*Dissolved oxygen, ppm	1.4	0.14	0	0
**Hydrogen Sulfide, H_2S, ppm	5	3	0	0
Total hardness, ppm as $CaCO_3$	80	40	10	2
Sulfate-carbonate ratio, $\frac{\text{ppm } Na_2SO_4}{\text{ppm } Na_2CO_3}$	1:1	2:1	3:1	3:1
Aluminum oxide, Al_2O_3, ppm	5	0.5	0.05	0.01
Silica, SiO_2, ppm	40	20	5	1
Bicarbonate, HCO_3^-, ppm	50	30	5	0
Carbonate, CO_3^{--}, ppm	200	100	40	20
Hydroxide, OH^-, ppm	50	40	30	15
***Total solids, ppm	3000-500	2500-500	1500-100	50
pH value, minimum	8.0	8.4	9.0	9.6

*Limits applicable only to feed water entering boiler, not to original supply.

**Except when odor in live steam would be objectionable.

***Depends on design of boiler.

Taken from Water and Its Impurities by Thomas R. Camp



18.500.000 BTU STEAM SYSTEM FOR OIL FIELD INJECTION

3. Water Quality Analysis

Industry must be in a position to know the quality of their source water before it can determine whether it can be used in a particular process. To provide this information the Industrial Waste Division initiated a comprehensive sampling program to provide a complete chemical analysis for the reclaimed water in its various stages of improvement. The program was designed to review the operational and seasonal variations of the chemical constituents which appear in the reclaimed water.

Complete chemical analysis on the samples of reclaimed water taken at the water pollution control plant were performed by personnel of the Industrial Waste Division Laboratory. The laboratory is certified by the State of California as qualified to perform chemical analysis on fresh water which is intended for human consumption. The Los Angeles County Health Department is conducting a coloform and virus sampling program which began in April, 1965. When it is completed criteria will be developed for the treatment of the effluent. All of the sampling and analyses performed by the laboratory staff was in accordance with the "Standard Methods for Examination of Water and Waste Water" which is published by the American Public Health Association (1965, Edition).

During the sampling program the tertiary treatment unit influent was taken from one of the oxidation ponds. It reflected the quality of sewage which had been in the oxidation ponds for approximately 60 days. Aluminum sulfate was added to the influent which then passed to either an air floatation tank followed by a dual sand filter or a sedimentation tank followed by a pressure sand filter. Chlorine was added to the reclaimed water which was discharged to a chlorine contact basin. After 24 hours in the basin the water was pumped to the simulated lakes for further studies.

A diagram of the sampling points used by the Industrial Waste Division is shown on page 93. The numbering of the points corresponds to the numbering of the points used by the Sanitation Districts. Point 1 samples the influent to the tertiary unit. Point 3 is located in the pilot tertiary treatment plant which is after flocculation and filtering. Point 4 samples the reclaimed water discharged from the tertiary unit. Point A samples the effluent before it is discharged to the oxidation ponds.

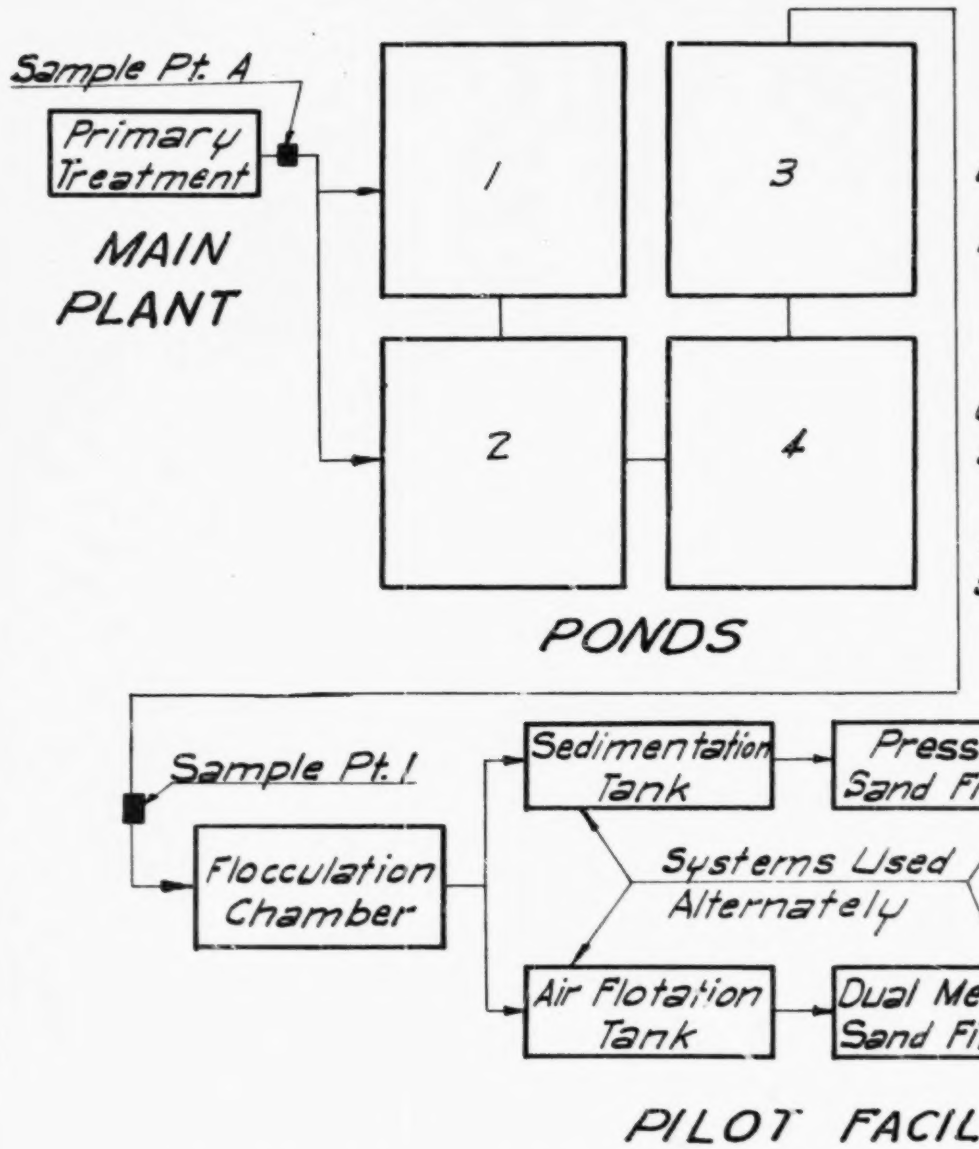
The graph shown on page 96 reflects the total dissolved solids concentration in the influent and effluent of the pilot tertiary treatment plant. Also shown is the total dissolved solids concentration of reclaimed water at Point 3 in the treatment plant. Fluctuation shown on the graph is attributed to intermittent operation of the tertiary treatment plant and the effect of the addition of chemicals in the treatment process. As operations of the plant become more continuous more uniform results should be obtained. The piping at the Water Pollution Control Plant and in the tertiary unit permits any combination of paths for the material under treatment. This may also account for some variations.

Table 12 presents the complete average chemical analyses for the effluent from the sedimentation tank, influent to the tertiary unit and the reclaimed water. Samples of the influent to the pilot tertiary treatment plant were also collected for a determination of oil and grease content. None of the samples taken had indicated the presence of oil or grease.

4. Water Quality in Los Angeles Area

Water in Los Angeles County is distributed by a large number of separate water companies. These companies furnish water from local water wells in their respective areas. Many of these companies cannot supply their demand for water from local wells and augment their supplies with imported water. Some of the water companies which supply water for industrial uses include the Metropolitan Water District, the Los Angeles City Department of Water and Power, the Southern California Water Company, the San Gabriel Valley Water Company and the Dominquez Water Corporation.

The Metropolitan Water District supplies softened Colorado River water to the Los Angeles Area. Los Angeles City supplies water from local wells. This is supplemented by imported water from Owens Valley. Owens Valley is located approximately 250 miles north of Los Angeles. Table 14 shows the chemical quality of several water supplies in Los Angeles County and the quality of the reclaimed water from the tertiary treatment plant.


Sample Pt. A
Primary Treatment
MAIN PLANT
1
2
3
4
PONDS
Sample Pt. 1
Flocculation Chamber
Sedimentation Tank
Air Flotation Tank
Systems Used Alternately
Pressure Sand Filter
Dual Medium Sand Filter
Chlorine Contact Basin
Sample Pt. 3
Simulated Recreation Lake
Sample Pt 4
PILOT FACILITY

SAMPLING SCHEDULE

Weekly Points 1, 3, 4

Monthly Point A,

ANALYSIS SCHEDULE

Oil & Grease analysis only on monthly sample taken at Point 1

A complete analysis for all other samples.

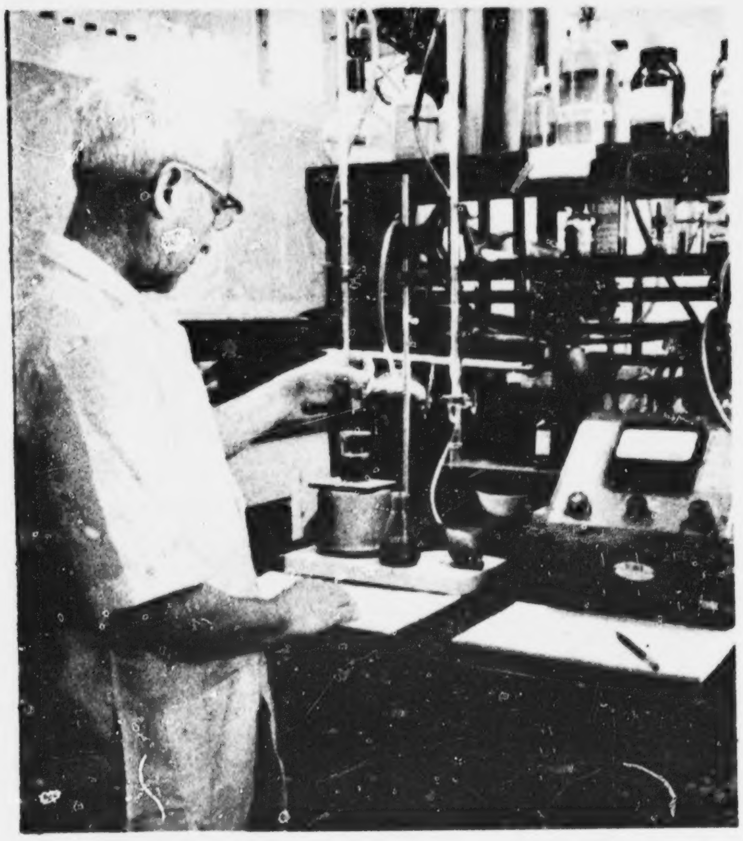
SAMPLING POINTS IN PROCESS FLOW DIAGRAM

FIGURE 12

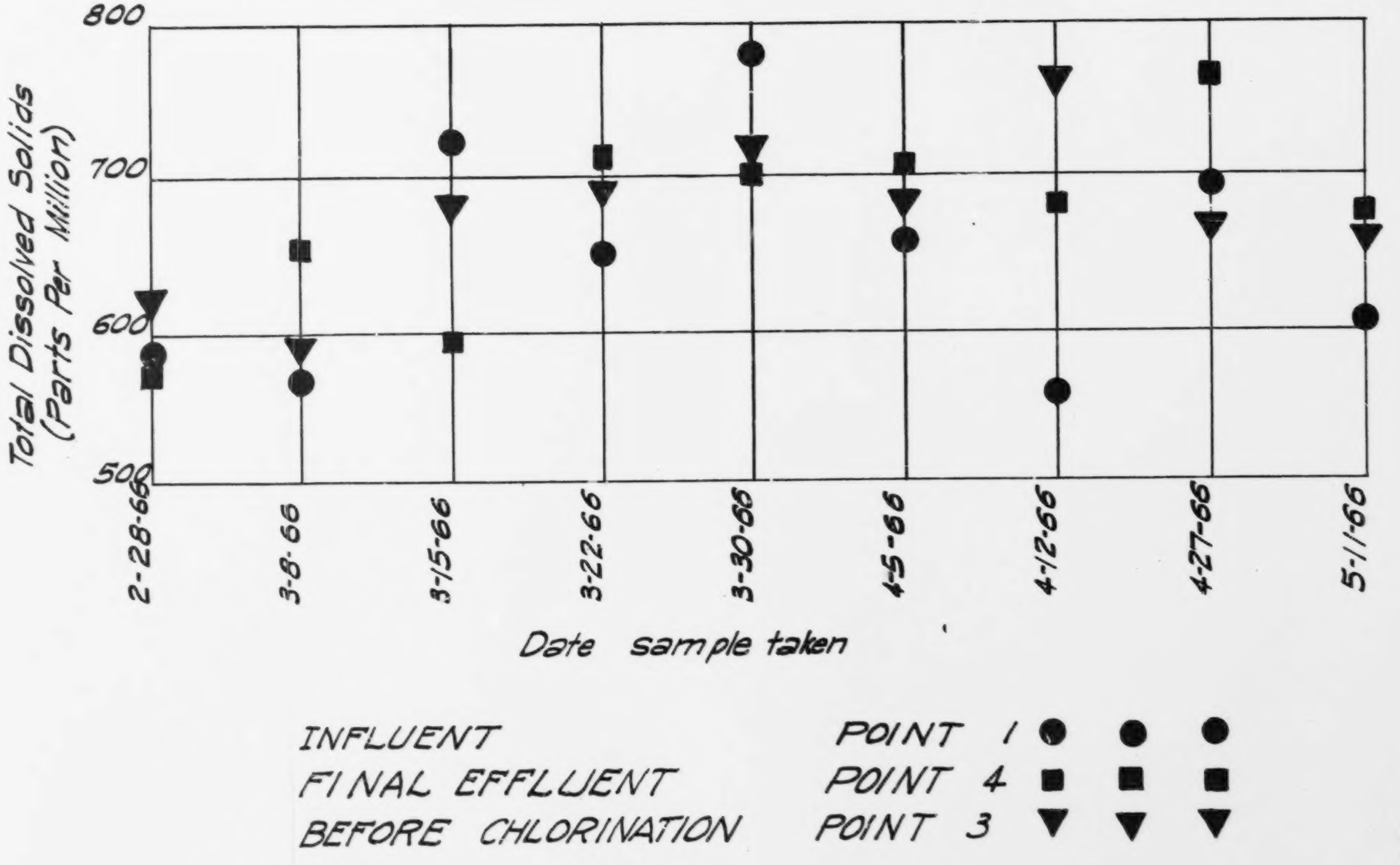
SAMPLING POINT NO. 4 FINAL EFFLUENT

SAMPLING POINT NO. 1
INFLUENT TO PILOT PLANT

SAMPLING POINT NO. 3
WATER BEFORE CHLORINATION



ANALYSIS IN PROGRESS AT INDUSTRIAL
WASTE DIVISION LABORATORY



TOTAL DISSOLVED SOLIDS AT
POINTS IN THE PILOT
TERTIARY TREATMENT PLANT

FIGURE 13

TABLE 12
CHEMICAL ANALYSES OF EFFLUENT FROM SEDIMENTATION TANK (POINT A) INFLUENT TO TERTIARY UNIT (POINT 1) RECLAIMED WATER IN TERTIARY UNIT (POINT 3) AND RECLAIMED WATER FROM TERTIARY UNIT (POINT 4)

Constituents	Average Concentration in Parts Per Million			
	Point A	Point 1	Point 3	Point 4
Calcium	14	17	30	30
Magnesium	6.5	12	5.7	6
Sodium	225	195	187	191
Iron	0	0	0	0.03
Manganese	0	0	0	0
Aluminum	0	0	0	0.01
Boron	0	0	0	0
Chromium, Hexavalent	0	0	0	0
Silica	26	26	20	21
Hydroxide	0	0	0	0
Carbonate	0	0	0	0
Bicarbonate	328	258	143	164
Chloride	62	69	70	72
Sulfate	157	161	275	266
Nitrate	0	0	0	0
Sulfide	2	0	0	0
Fluoride	1.6	1.4	0.5	0.6
Phosphate	13.3	21.3	0.2	0.4
Cyanide	0	0	0	0
pH	7.5	7.9	7.2	7.6
Hardness (as $CaCO_3$)	61	90	98	100
Alkalinity (as $CaCO_3$)	268	211	117	134
Carbon Dioxide (calc.)	16.8	5.2	16.0	8.5
Non-Carbonate Hardness	0	0	8	9.1
Conductance micromhos	860	832	896	901
Turbidity	35	84	8	7
Sodium Ratio	88.6	81.9	81.1	80.6
Total Dissolved Solids	668	630	660	668

TABLE 13

DOMESTIC WASTES

Human beings through their normal activities add many materials to the water which they use. Below is a table which indicates the increase in mineral constituents contained in residential sewage effluents over source waters.

Material	Range of Increase in PPM	
	Connell & Forbes	J.H. Feth
Ammonia	2-20	---
Silica	10-20	---
Phosphate	10-50	---
Nitrate	1-20	---
Chloride	25-125	---
Magnesium	5-20	3-6
Calcium	10-50	1-16
Alkalinity	30-100	100-150
Boron	---	0-0.1
Sodium	---	40-70
Chloride	---	20-50
Potassium	---	7-15
Total Nitrogen	---	20-40
Sulphate	---	15-30
Total Dissolved Solids	150-500	100-300

The above data could be used for further water reuse study. The amount of fresh water regularly introduced into a system and the contamination contributed by industry would all be factors that would have to be evaluated in deciding how many times the water which was used initially for domestic purposes could be recycled.

Source: C.H. Connell & M.C. Forbes, "Once-used Municipal Water as Industrial Supply", Water & Sewage Works 121, September, 1964.

J.H. Feth, "Nitrogen Compounds in Natural Water --A Review," Resources Research , (1966).

TABLE 14

CHECICAL ANALYSIS OF RECLAIMED WATER AND OTHER WATERS SUPPLIED IN THE LOS ANGELES AREA
(AVERAGE)

Constituents in ppm	1	2	3	4	5	6	7
Calcium	30	51	25	62	184	5	62
Magnesium	6	18	7	20	65	1	12
Potassium	----	5	4	4	----	----	----
Sodium	191	171	36	50	156	61	48
Iron	0.03	Trace	0.03	0.02	0	0	0
Boron	0	0.12	0.48	0.23	0	0	0
Silica	21	10.3	21	21	18	14	15
Carbonate	0	1	----	----	0	7	0
Bicarbonate	164	138	----	----	249	129	222
Chloride	72	103	19	41	95	6	22
Sulfate	266	306	28	129	665	17	90
Nitrate	0	1.0	0.7	7.8	42	2	0
Fluoride	0.6	0.4	0.60	0.39	----	----	0.6
pH	7.6	8.3	8.33	7.94	8.1	8.6	8.0
Hardness (as $CaCO_3$)	100	201	90	240	720	16	202
Carbon Dioxide (calc.)	8.5	1	----	----	2.8	0	----
Non-Carbonate Hardness	9.1	86	----	----	516	----	----
Conductance micromhos	901	1180	356	714	1630	228	583
Total Dissolved solids	668	736	215	428	1348	178	359

1 Reclaimed water from tertiary treatment plant.
2 Metropolitan Water District - softened Colorado River Water
3 Los Angeles City - Owens Valley Water.
4 Los Angeles City River Conduit - Mixture of several sources.
5 Saugus Area - Local well.
6 Lancaster Area - Local well near reclamation plant.
7 Huntington Park - Local well.

C. INDUSTRIAL WATER CONSUMPTION

The State of California Department of Water Resources Bulletin No. 124 Published in April, 1964, indicated that the total estimated annual fresh water use by industry in Los Angeles County was nearly 10,000,000,000 cubic feet. This is based on data accumulated for the years 1957, 1958 and 1959. Petroleum refining with its related industries and Food with its kindred products are the major fresh water users in Los Angeles County. A tabulation of these groups in the County and estimated annual amount consumed by these groups is shown on page 101. The number of industries in the Los Angeles Area has grown since, 1959, and it is reasonable to assume that industrial water consumption has also increased.

This bulletin also provides a breakdown by major industrial groups of the reported total annual water use in the State of California during the same 3 year period. A copy of this chart is shown on page 102. More than half of the total water intake of industry is used for cooling purposes. Page 103 shows the reported annual usage of water by industries in the State of California. This chart also indicates that less than 25 percent of the total intake water is treated prior to use.

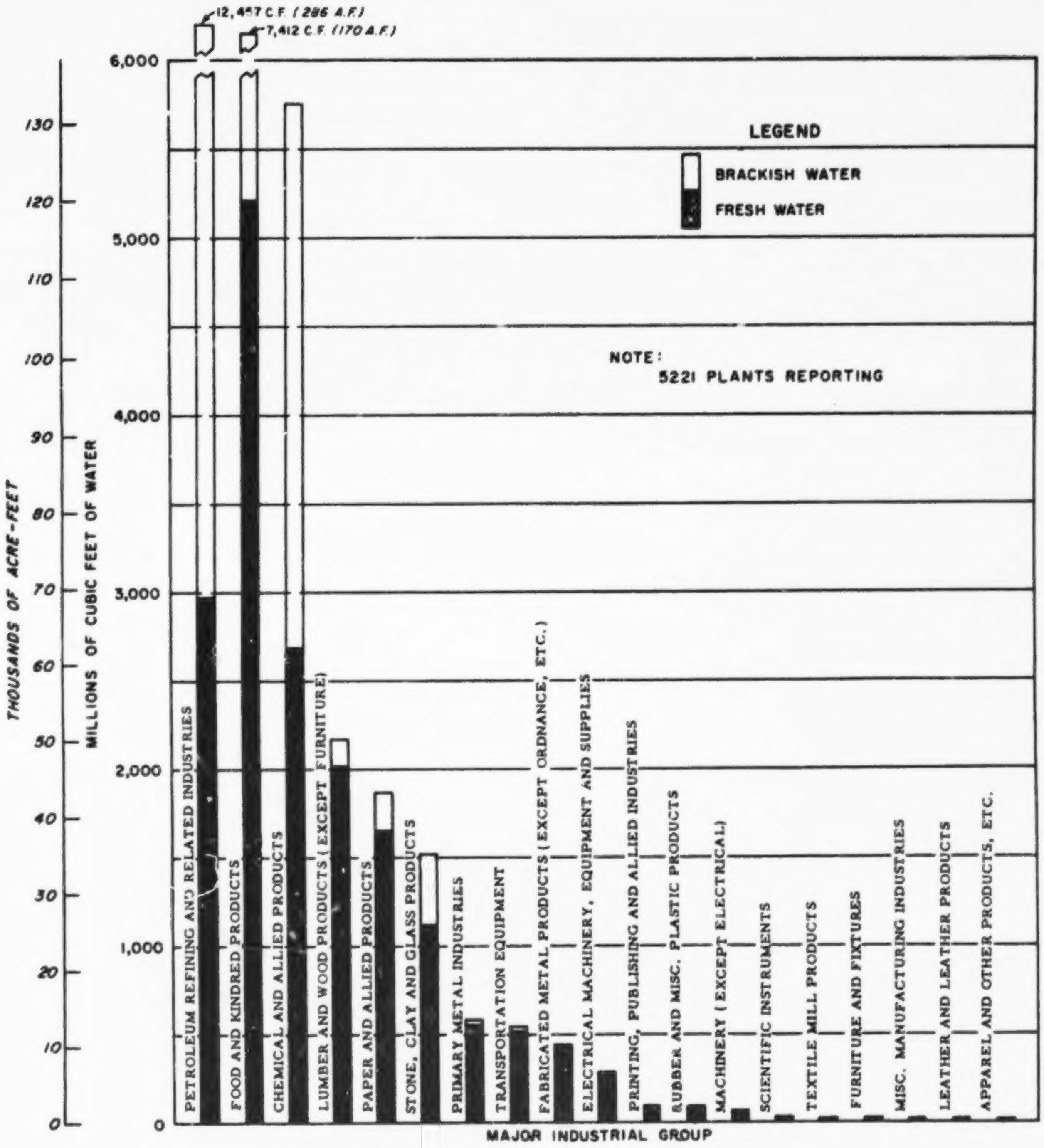
TABLE 15

ESTIMATED ANNUAL TOTAL FRESH WATER USE BY MAJOR INDUSTRY GROUP LOS ANGELES COUNTY

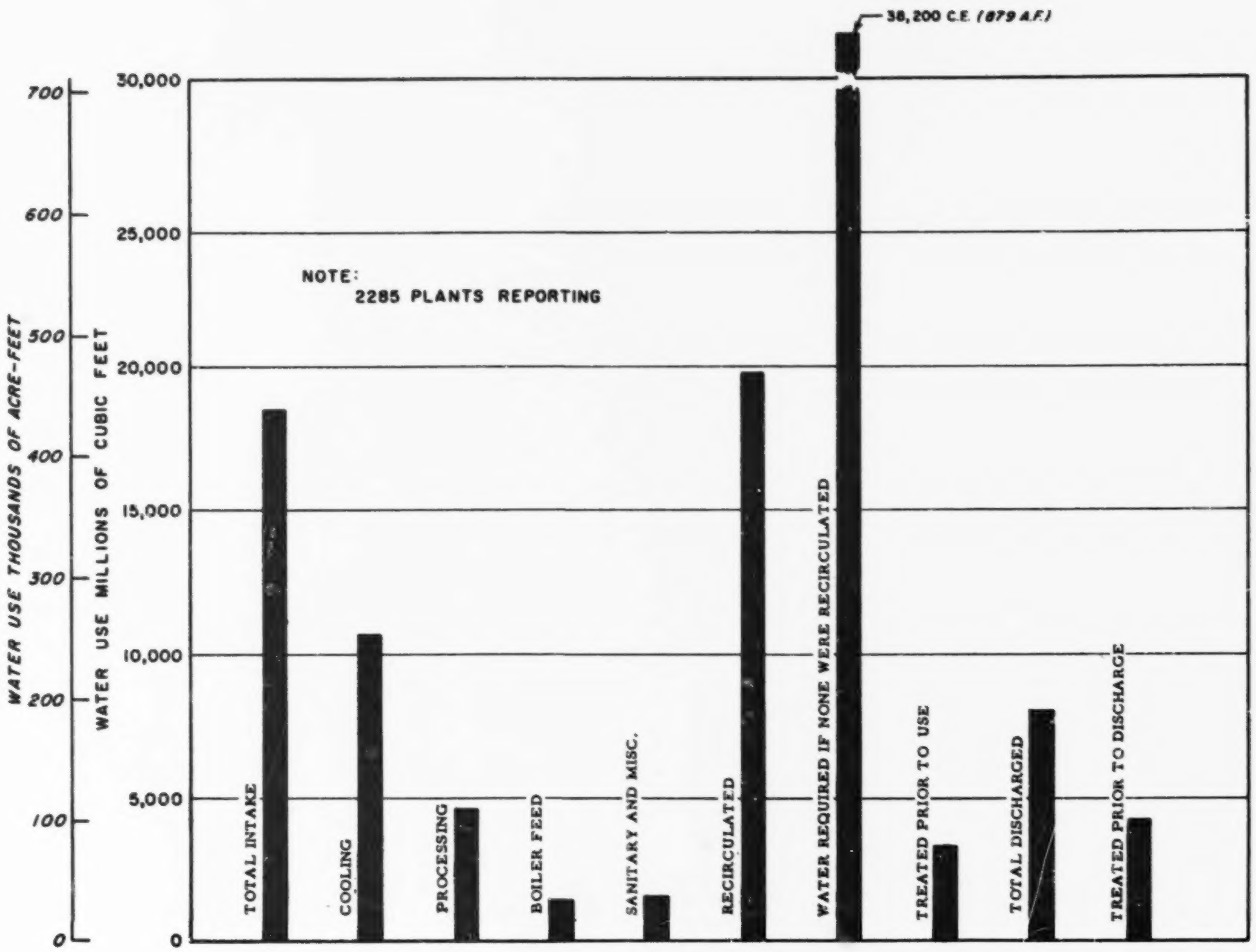
1957 - 1959

(CUBIC FEET)

MAJOR INDUSTRY GROUP	CONSUMPTION
ORDNANCE AND ACCESSORIES	29,383,000
FOOD AND KINDRED PRODUCTS	1,414,686,000
TEXTILE MILL PRODUCTS	32,159,000
APPAREL & OTHER PRODUCTS, ETC.	50,974,000
LUMBER & WOOD PRODUCTS EXCEPT FURNITURE	22,475,000
FURNITURE & FIXTURES	38,979,000
PAPER & ALLIED PRODUCTS	857,137,000
PRINTING, PUBLISHING & ALLIED INDUSTRIES	76,664,000
CHEMICAL & ALLIED PRODUCTS	961,497,000
PETROLEUM REFINING & RELATED INDUSTRIES	3,282,255,000
RUBBER & MISC. PLASTICS PRODUCTS	272,287,000
LEATHER & LEATHER PRODUCTS	6,132,000
STONE, CLAY, & GLASS PRODUCTS	314,118,000
PRIMARY METAL INDUSTRIES	241,510,000
FABRICATED METAL PRODUCTS, EXCPT.ORND.ETC.	899,291,000
MACHINERY, EXCEPT ELECTRICAL	182,285,000
ELECTRICAL MACHINERY, EQUIP. & SUPPLIES	205,672,000
TRANSPORTATION EQUIPMENT	712,838,000
SCIENTIFIC INSTRUMENTS, ETC.	53,801,000
MISC. MANUFACTURING INDUSTRIES	117,219,000
TOTAL ALL MANUFACTURES	9,771,363,000



REPORTED TOTAL ANNUAL WATER USE



REPORTED ANNUAL USAGE OF WATER

TABLE 16

NATIONWIDE GROSS FRESH WATER INTAKE 1959

INDUSTRY	MILLION GALLONS PER DAY
Automobile	249
Beet Sugar	336
Chemicals	9857*
Coal Preparation	97
Corn & Wheat Milling	103
Distilling	71
Food Processing	72
Machinery	13
Meat	144
Petroleum	1761
Poultry Processing	24
Pulp & Paper	4165
Soap & Detergent	57
Steel	10,156
Sugar Cane	180
Tanning	32
Textiles	128

* for 1962

Consumption is the difference betwen intake (fresh and brackish water combined) and the amount of water discharged. Some of the ways in which this loss can occur are evaporation from ponds, cooling towers, incorporation in the product, disposal to deep wells, and spray irrigation.

For industries reporting a gross fresh and brackish water, intake was 30.46 billion gallons per day (bgd) their discharge was 28.43 bgd giving a consumption of 2.03 bgd or 6.7%. This is roughly 2% of the water consumed in the United States by all users including irrigation steam, electric utilities, federal installations, mineral industries, rural domestic supplies, and municipal water systems.

Below is a list of consumption percentages for various industries. In some plants water is first used for cooling and then re-used for processing while in others the reverse is true.

INDUSTRY	WATER CONSUMPTION AS % OF INTAKE
Automobile	6.2
Beet Sugar	10.5
Chemical	5.9
Coal Preparation	18.2
Corn & Wheat Milling	20.6
Distilling	10.4
Food Processing	33.6
Machinery	21.4
Petroleum	7.2
Meat	3.2
Poultry Processing	5.3
Salt	27.6
Soap & Detergent	8.5
Steel	7.3
Sugar Cane	15.9
Textiles	6.7

TABLE 17. VARIANCE IN UNIT INDUSTRIAL WATER REQUIREMENTS

	CONSUMPTION, GALLONS			
PRODUCT OR USER	MAX.	AVE.	MIN.	CONSERVATION TECHNIQUE
Steam power generation, kwhr	170	80	1.32	Recycling through cooling towers
Petroleum refining, gal. crude oil	44.5	18.3	0.8	Information insufficient
Finished steel, tons	65,000	40,000	1,400	Complete recycling through cooling towers reuse of all flows
Soaps, edible oil, lb.	7.5	---	1.57	Recycling through cooling towers and colloidair separation
Butadiene, lb.	305	160	13	Recycling through cooling towers
Glass containers, ton	667	---	118	Cooling water recirculated

Taken from: "Water for Industry" by Jack B. Graham & Meridith Burrill

D. POTENTIAL INDUSTRIAL USES

During the initial phase of this study it was decided that the water quality requirements of the various industrial processes and operations should be determined. Then knowing the quality of water available at the water reclamation plant it would be relatively simple to determine which specific industrial processes could use water from a particular stage in the reclamation cycle.

Based on experience gained in the initial phase it was decided that the primary source of reliable data would result from personal contacts with industries in the Los Angeles Metropolitan Area. This direct approach would provide an informal meeting with representatives of all segments of a large number of industries. It permits an explanation of the research program and affords management an opportunity to ask questions and even offer suggestions.

This phase of the study continued the review of all available literature on the subject of water quality requirements for various industrial operations and processes. To accomplish this goal, correspondence was directed to individual companies, professional societies, Federal and local governmental agencies and individuals concerned with or interested in water conservation and water reuse.

The effort to correspond with all segments of industry, throughout the nation was abandoned. It was found that only a small fraction of the companies replied to the letters and questionnaires. It is thought that the primary reason for the poor response is that most industries do not know their water quality parameters. Industries adapt to the available source of water and treat that source to meet their quality requirements.

The questionnaires returned to this office were often incomplete. This experience parallels that of the National Association of Manufacturers in their survey on Water and Waste Quality. The subject is covered in their publication titled "Water in Industry" which states:

> Information was requested regarding the BOD, COD, chlorine demand, total solids, pH and other characteristics of raw water and of waste water before and after treatment.

It was known that many plants determine few, if any, of these characteristics on a routine basis, but it was hoped that sufficient replies would be received to permit a presentation of typical ranges. Responses were so scanty, however, as to defy any meaningful analysis

1. Review

The review of scientific and technical publications for data in the fields of water reuse and water conservation was continued. This information was supplemented with correspondence directed to specific research groups, manufacturers, organizations and individuals concerned with water reuse.

It is estimated that approximately two-thirds of the water intake by industry is for cooling purposes. The quality of the water used in cooling towers varies considerably. Normally, cooling tower water is maintained below 2500 ppm total dissolved solids. The American Potash and Chemical Plant in Trana, California uses brakish water as makeup in its cooling tower. This water has total dissolved solids as high as 33,500 ppm. Organic compounds are added to their cooling tower water and algae are present in the recirculated supply.

The petroleum refining and related industries in California during the 1957 through 1959 period had an annual intake of 12,457,000,000 cubic feet of water. Approximately three-quarters of this amount was brakish water. The petroleum industry uses complete treatment systems for producing steam to be used in oil field thermal recovery operations. The steam is injected into oil wells as a part of a program for increasing crude oil production. The units can use water of very poor quality.

The boiler manufacturing industry has conducted extensive reasearch into the water quality requirements for boiler feed water. The tolerances of impurities in raw water for steam generation are relatively high for low pressure boilers. This is due to the introduction of boiler compounds which make internal water treatment practicable. With operating pressures above 400 psi, water which more nearly approaches deaerated distilled water quality is desirable. Table 11 suggests limits for boiler feed water.

The food and kindred products industry in the State of California annual water intake during the 1957 through 1959 period was more than 7,000,000,000 cubic feet. Approximately a third of this was brakish water. If the reclaimed water at the Lancaster Reclamation Plant is found to be free of bacterial and viral contamination by the Los Angeles County Health Department, it may be acceptable to use it for cooling purposes in food processing installations. A great deal of further research is required in this area.

Reviewing the literature available indicates that most of the plant managers are not in a position to allocate sufficient time and money to determine their water quality parameters. Even in the field of the amount of water required to produce a unit of product there is a great divergence of opinion. This is indicated in Table 17. No doubt some of the variance is due to the difference in the quality of source water.

2. Industrial Use of Water

Plant managers and operators in the Los Angeles Area were personally contacted. This personal contact afforded an opportunity to discuss the research program and request their participation. Apparently some of them were concerned that we were looking for violations of some ordinance. Once these individuals understood that the objective of this program is to determine water quality criteria their cooperation was assured.

Unfortunately, the majority of plant operators were not aware of the water quality requirements for their particular processes. The water used in their operations has not affected the quality of the finished product. Therefore, it has been unnecessary to devote time and money in order to determine water quality parameters. In instances where the product has been affected by the quality of the water, the company did research to identify source of the trouble. Once identified, equipment was installed to remove the constituent causing the difficulty. This equipment is regenerated or recharged whenever the defect begins to appear in the finished product. The point at which a defect begins to appear can be affected by temperature, composition of the part or other constituents in the source water. These constituents can vary as local water companies usually mix water from several sources.

The plants reviewed included textile, paper, chemical, petroleum, rubber, leather, metal manufacturing and metal finishing facilities. Operators were shown the chemical analysis of the effluent from the tertiary treatment plant. Their response was that they could use the reclaimed water in their processes. Some indicated that the water would have to be treated before it could be used in some of their operations. These same plants currently treat water for operations at their present locations. The additional cost, if any, of treating the reclaimed water over their current water costs is not expected to be significant.

The main concerns of the operators of installations which currently use treated water in their operations are:

1. Cost of the reclaimed water.
2. Cost of bringing the reclaimed water into the plant
3. What is the year round consistency of water quality of the reclaimed water.

Food and kindred product facilities were not reviewed. This is because of the connotations attached to the use of sewage effluent for any purpose other than discharge to the ground.

The need for water is common to agriculture, industry, and the home. With a growing population and expanding industrial capacity it is essential that we use this abundant resource wisely. Industry discharges approximately 93% of the water it withdraws from wells, lakes, rivers, and tidal estuaries. The 7 percent it consumes is about 2 percent of the water consumed in the United States by all users of water.

In a survey conducted by the National Association of Manufacturers it was estimated that the replies received represented 90% of the total water intake by the manufacturing industry. Following is a tabulation of the water used by these respondents. The term "manufacturing industry" does not embrace the minerals industry, metal and nonmetallic minerals, coal mining, crude petroleum mining, and natural gas extraction. It does include refineries and coal preparation plants.

INDUSTRIAL USERS OF WASTE WATER EFFLUENT

Industry	Source of Effluent	Uses
Bethlehem Steel Co. Sparrows Point Plt., Md.	Baltimore Back River Plant	Processing and cooling
Kaiser Steel Plant Fontana, California	Plant sanitary waste water treatment plant	Processing
Columbia-Geneva Steel Provo, Utah	Plant sanitary waste water treatment plant	Processing
Los Alamos Scientific Lab. Los Alamo, N.M.	Los Alamos Sewage Plant	Power plant Cooling water
Grand Canyon National Park	Park Sewage Plant	Power plant use
Southern Nevada Power San Bernardino, Cal.	Las Vegas County Sewage Plant	Power plant Cooling water
Cal. Elec. Power Co. San Bernardino, Cal.	San Bernardino Sewage Plant	Power plant cooling water
Cosden Petroleum Corp. Big Spring, Texas Ref.	Big Spring Sewage Plant	Boiler water
Texas Company Refinery Amarillo, Texas	Amarillo Water Reclamation plant	Cooling and Boiler water
Southwest Public Service Company	Amarillo Water Reclamation	Power plant cooling water
El Paso Natural Gas Prod. Co., Butadiene and Styrene Plansts and Refinery, Odessa, Texas	Odessa Sewage plant	Cooling and boiler water
Champlin Refining Co. Enid, Oklahoma	Enid Sewage Plant	Cooling and boiler water
Eight Copper Recovering Companies in New Mexico and Arizona	Nearest available sewage effluents	Copper recovery

TABLE 18

DIVISION OF INDUSTRIAL USES OF WATER

A significant portion of all industrial water is used in cooling systems. The table below gives the percentage relation of cooling water and non-cooling water in the waste discharge from several industries.

INDUSTRY	COOLING	(PROCESS AND OTHER USES) NON-COOLING
Automobile	21%	79%
Beet Sugar	95	5
Chemical	65	35
Distilling	84	16
Meat	25	75
Petroleum	82	18
Soap & Detergent	66	34
Steel	66	34
Sugar Cane	69	31
Textiles	10	90

Taken from: "Water In Industry", National Association of Manufacturers, January, 1965.

TABLE 19

SUMMARY OF INDUSTRIES

USING WATER TREATMENT, BY INDUSTRY TYPE

Each industrial plant has its own water quality parameters. These depend on the process or product contemplated. The percentages of plants utilizing water treatment facilities are shown below. Types of facilities include filtration, softening, ion exchange, and settling.

INDUSTRY	PERCENT WITH WATER TREATMENT FACILITIES
Automobile	58%
Beet Sugar	36
Corn & Wheat Milling	92
Distilling	79
Food Processing	51
Machinery	53
Meat	57
Petroleum	90
Photographic	100
Soap & Detergent	75
Steel	60
Sugar Cane	20
Tanning	16
Textiles	61

TABLE 20

INSUSTRIAL USE OF BRACKISH WATER

Brackish water is usually thought of as water containing more than 1,000 parts per million of dissolved solids. A report published by the National Association of Manufacturers indicates that the amount of brackish water used by the chemical industry is approximately 35% of the total quantity of water used. Other plants whose total fresh water intake was 17.6 billion gallons per day reported an additional intake of 3.0 billion gallons per day of brackish water, or 15% of their total intake. The relation of intake of brackish water to total water intake for some industries is shown below:

INDUSTRY	BRACKISH WATER AS % OF TOTAL INTAKE
Corn & Wheat Milling	15
Food Processing	6
Meat	4
Petroleum	48
Pulp & Paper	11
Salt	19
Soap & Detergents	45
Steel	7
Sugar Cane	5

3. Recirculation and Reuse

Plants reporting use of 17.64 billion gallons per day of fresh water reported that 29.11 billion gallons per day of additional water would have been required if there had been no reuse.

To illustrate, the automobile industry's actual water intake in 1959 was 248.7 million gallons per day and the additional amount of water it would have required if reuse had not been practiced was 402.7 million gallons per day. Dividing 402.7 by 248.7 gives the reuse factor of 1.62. Each gallon of water intake was therefore used 2.62 times before ultimate discharge.

There are numerous ways in which water could be recycled or reused in industrial plants. The fact that this is not a more common practice is due at least in part to the manner in which sewers have been installed. When all waste waters are dumped into a common sewer, separation for recycling can involve some very expensive reconstruction.

The best time to plan recycling operations is before the industrial plant is built. This was done at the Fontana Works of the Kaiser Steel Corporation because water was scarce and costly. In this plant the industrial water is supplied through a series of individual systems. The blowdown of one system becomes the supply for the next. Quality requirements determine the sequence, and the final effluent is used for quenching slag, cooling coke, and spraying to arrest dust. The water-recycling and reuse systems at the Fontana Works reduce the imput of water per ton of steel to 1600 gallons, but most of this is consumptive use. The usual amount per ton of steel is 65,000 gallons, most of which is non-consumptive.

The need to appropriate large sums of money for the purpose of importing fresh water into Southern California has led water users in greater Los Angeles County to reevaluate the uses of water. The City of Los Angeles Department of Water and Power is currently making studies of the feasibility of using sewage effluent to provide cooling water and steam for their various power generating installations. Although the studies have just been undertaken, and data have not been resolved, projections could call for the use of 4 mgd of sewage effluent to replace fresh water at the Valley Steam Plant in the San Fernando Valley.

TABLE 21

TABULATION OF INDUSTRIAL USAGE OF RECYCLED WATER

Many industries recirculate portions of their intake water. Below is a list of the daily quantities of additional process and cooling water which would have been required if no water was recirculated or reused.

The ratios shown below for various industries are the ratios of the additional amount of water to the fresh water intake that would be required if plant water were not reused.

INDUSTRY	RATIO
Automobile	1.62
Beet Sugar	0.48
Coal Preparation	13.91
Corn & Wheat Milling	0.22
Distilling	0.51
Food Processing	0.19
Machinery	4.50
Meat	3.03
Natural Gas Transmission	1.32
Petroleum	6.62
Photographic	3.20
Poultry Processing	6.56
Pulp & Paper	2.02
Salt	0.12
Soap & Detergent	2.08
Steel	0.60
Tanning Leather	0.04
Textiles	0.30

4. Other Water Treatment Processes

In our research program we have obtained information on various methods of treating waste water. While a process has already been selected for the Lancaster Treatment Plant, we present this data in the event that it is desired to further upgrade the plant effluent. One of these other methods might then prove more satisfactory.

Research by the laboratory of Rohm and Haas has shown that a modification of the DeSal Process which is used for treating acid mine wastes can be employed for treating secondary sewage effluent. As described by the laboratory the secondary effluent is passed upflow through a bed of their Amberlite IRA-68 in the bicarbonate cycle. The resulting effluent is then treated with a small quantity of bentonite and a catronic flocculant, aerated and limed in proportion to its hardness concentration. The effluent should now be clear partially desalinated water essentially free of nitrates, phosphates, chlorides and COD. If salinity is too high it may be reduced by further treatment of the treated effluent. The table below compares the composition of a secondary sewage effluent before and after treatment by the modified Desal Process.

	INFLUENT	EFFLUENT
pH	7.3	8.5
Turbidity	Very Cloudy	Clear
COD	1001	15
Hardness (ppm $CaCO_3$)	98	30
Nitrate	25	0.8
Phosphate	33	<1
Specific resistance, ohm/cm	1700	2900
Chloride	45	5
Alkalinity	160	150

The cost for treating the above descirbed sewage effluent is from $0.15 to $0.20 per 1,000 gallons. The capital cost is approximately $175,000 for a 1,000,000 gallon per day plant.

The De Sal process, just discussed, also reduces the dissolved mineral content of water. The build up of minerals in water, especially water which is to be reused, can constitute a very significant problem.

Below is a listing of some of the newer processes which are being studied by industry. It may be feasible to adopt one or more of them to reduce the total dissolved solids content of the water reclaimed at the plant, or at particular problem industries if it becomes necessary in the future.

a. Vapor retreat flash

b. Vapor compression with rotary heat transfer surface

c. Wiped film evaporator

d. Improved vapor compression with drop wise condensation

e. Improvements in electrodialysis

f. Osmionic process

g. Electrolytic System

h. Adsorption in porous electrodes

i. Osmotic

j. Solvent extraction

k. Solar distillation

l. Direct Freezing

m. Direct freezing secondary refrigerant

n. Direct freezing secondary refrigerant and control of crystal size

o. Gas Hydrate

p. Ion-exchange pretreatment

As a part of evaluating pretreatment costs, this office is accumulating statistics for all industrial and commercial discharges. After it is assembled and evaluated it will be possible to determine the cost of maintaining a particular quality of effluent from a specific industry or the water reclamation plant.

Neutralization of various acid wastes is one of the most common occurrences in industry. Below are some of these costs. The table is based on a 5 percent solution of the particular acid listed and shows the quantities of various alkalies required to neutralize a 100-gallon solution.

ACID	POUNDS ACTUAL ACID CONTENT	POUNDS SODA ASH	POUNDS CAUSTIC SODA	POUNDS ANHYDROUS AMMONIA
Acetic	41.96	36.84	27.92	11.88
Chromic	43.28	45.88	34.62	14.72
Citric	42.54	32.19	24.29	10.32
Muriatic	42.73	62.0	46.8	19.89
Nitric	42.79	35.99	27.13	11.54
Phosphoric	42.83	69.47	52.38	22.29
Sulfuric	43.05	46.6	35.2	14.95

Anhydrous Ammonia $0.03/lb, Soda Ash $0.0215/lb, Caustic Soda $0.035/lb. (delivered price in Los Angeles Area-1967)

The determination of costs for removing particular mineral constituents is more complex as it is affected by other materials present in the solution. To arrive at a cost for a particular industry or for a varying quality of water supply would require considerably more study.

5. Dual Water Stystems

If the water reclaimed at the reclamation plant is to be used by industry it must first be delivered to the industry site. This would normally involve a dual water system, one for potable water and the other for reclaimed water. Before these dual systems are installed it will be necessary to weight their advantages against their disadvantages.

The use of a dual water system offers economic advantages where various qualities of water are required in a single plant. An example would be a facility which requires a very high quality of water for use in boilers, and the usual domestic supply for drinking and other purposes. Because boiler feed water requires the greatest degree of treatment it is the most expensive to produce. The domestic supply is usually furnished by a local utility at a nominal cost. It would be a waste of money in an installation of this type to treat all of the water used in this plant to the degree required for boiler feed purposes and then use it in cooling towers or for domestic purposes. Using boiler feed water for domestic purposes would most probably bring complaints about its taste from the personnel in the plant.

The use of dual water systems also has disadvantages. It requires the building and maintaining of at least two complete and separate systems of pumps and piping. It is difficult to prevent interconnection between the two systems. Therefore, there is the danger that the lower quality water may pollute or contaminate the higher quality water. In some instances this may result in contaminated water being used by humans for drinking and washing purposes. In these instances it may be safer to the health of the personnel in an installation and also more economical to use a higher quality of water for all purposes.

For use of reclaimed water in industry in Antelope Valley, a separate supply system to the companies using the water would have to be considered. The cost would necessarily be much greater than for an in-plant dual water system.

E. CONCLUSIONS

The information compiled in this study indicates that industry can use the water from the water pollution control plant. Reclaimed water will be used when it becomes economically competitive with other sources of industrial water.

During this phase of the study no attempt was made to prepare a comprehensive list of potential industrial uses for reclaimed water. No consideration was given to determining methods for distribution of this water to prospective users. Other considerations such as the economics of this water source, availability of transportation and location of markets for products were not reviewed.

A few industries, because of stringent quality requirements in finished products, soften or demineralize portion of the water used in their operations. These industries would be required to treat their water regardless of the source.

Other conclusions from the study:

1. The primary question of all the individuals in industry who were contacted was "What will it cost?" It was evident that the economics of the reclaimed water is the dominant factor. We have investigated some costs in this report; more work is necessary involving mineral removal for particular industries and separate piping costs.

2. We have reviewed data and discussed briefly with industry other methods of polishing or treating the sewage effluent. If a different quality of effluent, than is presently produced, could more readily be used by an industry, these methods should be considered.

3. The domestic use of water contributes certain contaminants, quantities of which have been listed. These should be used in further studies on the number of time the effluent is to be recycled.

F. PROBLEMS EXPERIENCED

Some of the conclusions made are incomplete. There are many factors which must be considered in the total picture of water reuse. It is therefore recommended that an environmental engineering review of the entire basin be made. It should incorporate a program to:

1. Activate a water quality sampling schedule as soon as the water renovation plant has been put into operation. This would afford an opportunity to evaluate the data obtained at the pilot facility with the actual results in the full size plant. This program should be continued for a least a year so as to reflect seasonal or other variations in water quality.

2. Include studies for possible supplemental methods of treating sewage effluent to improve the mineral quality of the reclaimed water to the equal of local potable water supplies. It could then be injected into existing aquifers without degrading existing waters.

3. Review the feasibility and economics of treating industrial wastes at their point of origin versus centrally located treatment.

4. Review the feasibility of developing industrial parks or complexes where a particular sector would be restricted for specific purposes. This would concentrate industries with similar wastes in single areas. These wastes could then be collected at a single point for treatment and then discharged to the sewerage system, reused or transported by pipeline to another sector of the industrial complex for use in another industrial process which could utilize water of such quality. This would continue until the water has to be discarded.

5. Examine the feasibility of separate disposal systems, treatment facilities and formation of industrial waste disposal districts.

6. Investigate the use of the reclaimed water in a central heating and refrigeration installation. The steam and refrigerant could be piped to industries in the immediate area.

7. Review the feasibility of transporting the reclaimed water by pipeline to areas such as Saugus which use water from aquifers of much poorer quality.

8. Review feasibility of using this water for addition to Feather River Water.

9. Investigate utilization of some of the water from the teatment plant for irrigation of freeway rights of way.

10. Review the possibility of ocean disposal for the concentrated chemical wastes and sludges produced in the treatment of sewage, industrial wastes and water improvement processes.

During the search of industrial users, it was found that plant managers are primarily concerned with costs of using reclaimed water. Other concerns are what quality is the water, and perhaps more importantly, a reticence to discuss plant operations. This may be due to a fear of potential governmental control of plant policies.

PART VI

SOIL RECLAMATION STUDIES

A. OBJECTIVES

Much of the land in the Antelope Valley area is barren desert. The native soils contain unusually high concentrations of elemental boron. The land also is plagued by high concentrations of salts and underlying layers of impermeable clay. These conditions render the land incapable of supporting plant life.

During the course of the initial project research relating to tertiary treatment, it was decided to expand the research to include soil reclamation as a potential use for the product water.

This program was conducted by a special consulting firm, Engineering-Science, Inc. The study investigated the possibilities for the use of treated waste water as a leaching agent and digested sludge as a conditioner for the alkali soil.

Specific objectives of the soils research program were as follows:

1. To collate and review soil and water information pertinent to reclamation of saline-alkali soils.
2. To evaluate the degree of soil salinity and boron concentration at the project site.
3. To implement a laboratory experiment for bench scale investigation of different methods of soil reclamation and to study plant response to these methods.
4. To implement a pilot experiment to test various methods of soil reclamation in the field and to obtain additional information as to the growth characteristics of plants in saline-alkali soils subjected to different treatments.
5. To develop a list of suitable plant species for the proposed park area.
6. To prepare recommendations for implementation of grading, reclamation, leaching, and irrigation of the project area.

During the course of this research, a program of soil and water sampling and analysis was carried out to determine the degree of salinity of the soils in the project area and to evaluate the suitability of various sources of water supply for soil reclamation and irrigation purposes. A bench scale soil reclamation and plant growth experiment was carried out in the greenhouse to study the effectiveness of various chemical amending agents in reclaiming the saline-alkali soils of the project area. The results of this experiment were further verified and complemented by a pilot field study during which a soil reclamation and plant growth experiment were conducted in the field.

Practical recommendations for implementation of a soil reclamation program and selection of appropriate plant species for the proposed park area were developed on the basis of the over-all results of this research. These recommendations specify in detail the kind and quantity of amending agent required, method and extent of leaching operations, design of a drainage system for leaching and irrigation of the park area, quick testing methods for monitoring the progress of soil reclamation, leaching requirement during irrigation of the park area, and suitable plant species for the proposed park area.

B. THEORY OF SOIL RECLAMATION

Excessive concentrations of soluble salts or exchangeable sodium or both may impair or prevent plant growth in the soil. Saline or white alkali soils are those soils that contain excessive quantities of soluble salts in their soil solution. Alkali soils are those soils that contain a high concentration of exchangeable sodium on their exchange complex. These soils are sometimes referred to as black alkali soils. Finally, saline-alkali soils are those soils that contain both an excessive concentration of free salts and exchangeable sodium.

The criteria for classification of saline and alkali soils is based on the determination of electrical conductivity and percentage of exchangeable sodium in the soil. Exchangeable sodium expressed in percent is the amount of this ion on the soil exchange complex. The United States Salinity Laboratory (Reference 14) has developed a scale for relating electrical conductivity of soil saturation extract to crop response, (Table 22). This scale provides guidelines as to the concentration of soil salinity.

The criterion for designating alkali soils is based on the exchangeable sodium percentage or the soluble calcium percentage. An exchangeable sodium percentage of 15 has been mentioned as the limit for non-alkali soils. In terms of soluble calcium percentage of the soil saturation extract the limit can be set at 30 percent with very bad soils having a soluble calcium percentage of 5 or less (Reference 13). Saline-alkali soils have both a high concentration of free salts and a high percentage of exchangeable sodium.

TABLE 22

CONDUCTIVITY OF SOIL SATURATION EXTRACT VERSUS PLANT RESPONSE

Conductivity of Soil Saturation Extract millimhos/cm at 25° C	Plant Response
0-2	Salinity effects mostly negligible
2-4	Yields of very sensitive crops may restricted
4-8	Yields of many crops restricted
8-16	Only tolerant crops yield satisfactorily
16	Only a few very tolerant crops yield satisfactorily

Source: Reference 14

Note: Reference numbers refer to references cited in Section E of Part X, BIBLIOGRAPHY.

In addition to excessive salts of sodium and/or adsorbed sodium ions alkali soils may contain high concentrations of boron. Boron is essential for plant growth at very low concentrations but when the concentration of boron in the soil saturation extract exceeds one part per million some plants fail to grow. Tentative permissible limits of boron in the saturation extract of soils as given in the report by United States Salinity Laboratory (Reference 14) are as follows:

> "Concentrations below 0.7 PPM boron probably are safe for sensitive plants, from 0.7 to 1.5 PPM boron is marginal, and more than 1.5 PPM boron appears to be unsafe."

Boron is usually found in the forms of boric acid and borax which are soluble in water. In addition the so-called borosilicate minerals also contain small amounts of boron. These minerals are not readily soluble in water and as a result they are not leached from the soil by rain or irrigation water. These minerals supply boron to plant roots and are the principal source of boron for plants (Reference 13).

1. Methods of Reclamation of Saline, Alkali, or Saline-Alkali Soils

Saline, Alkali, or saline-alkali soils can be reclaimed by removing the excessive free salts from the soil, by replacing the adsorbed sodium ions in the exchange complex by calcium ions, or by applying both remedies together.

In most cases the excessive free salts in the saline soil consist of sodium and chloride salts which are quite water soluble. Therefore saline soils can be easily reclaimed by generous application of water and removal of the leachates through natural or artificial drainage. Alkali soils on the other hand are not reclaimable by leaching alone because sodium ions are adsorbed on the soil exchange complex and will not be removed until other ions of higher valence and/or smaller hydrated radius replace them (Reference 2). Calcium ions possess both of these requirements, i.e. they have a valence of two compared to the valence of one for sodium and also their hydrated radius is smaller than that of sodium. Therefore, to reclaim alkali soils an amending agent which contains calcium or releases soluble calcium from normally insoluble calcium salts in the soil should be added to the soil.

This action should be followed by leaching to carry away the sodium salts that are released by the interaction between soil and the amending agent. In order to reclaim saline-alkali soils two steps should be taken. The first step involves the removal of free salts by simple leaching and the second step consists of addition of amending agents to release sodium ions from the soil exchange complex. It has been suggested that these steps should be carried out sequentially (Reference 14) but in order to accelerate the process of soil reclamation and also to benefit from the improved soil permeability resulting from the effect of amending agents it is preferable to add the required amount of amending agents to the soil and subject the soil to extensive leaching afterwards.

When high concentrations of boron exist in the soil the best method of reducing this concentration is by extensive leaching of the soil and provision of good drainage for removing the leached salts and boron. An experiment conducted by the United States Salinity Laboratory (Reference 14) illustrates the large quantities of leaching water that may be required. In this experiment the initial concentration of boron in the saturation extract was 54 ppm. After the passage of 4 feet of water, the concentration was 6.9 ppm; after 8 feet it was 2.4 ppm; and after 17 feet it was 1.8 ppm.

2. Classification of Amending Agents

Amending agents are chemical substances that contain calcium or result in the release of calcium in soluble form in the soil solution. Sulfur, sulfuric acid, lime-sulfur, gypsum, iron sulfate, aluminum sulfate, and limestone are some of the common amending agents that are used for soil reclamation. Table 23 shows the relative efficiencies of these amending agents in terms of the amount of each agent that is required to release the same quantity of sodium sulfate from the soil adsorption complex (Reference 10).

3. Chemical Interaction Between Soil and Amending Agents

Each of the above amending agents interacts with soil to release the adsorbed sodium ions from the exchange complex. Some of these agents achieve this by direct interaction while others trigger two or more reactions for achieving the same result. Following is a brief description of the chemical interactions that take place when each of the above agents is added to an alkali soil.

TABLE 23

RELATIVE EFFICIENCIES OF SOME COMMON SOIL AMENDMENTS

Amendment	Tons Equivalent to One Ton of Gypsum	Tons Na_2So_4 Released to Drainage Water
Sulfur	0.19	0.83
H_2SO_4	0.57	0.83
Lime-sulfur, 24% S	0.79	0.83
Gypsum (Pure)	1.00	0.83
$FeSO_4 \cdot 7\ H_2O$	1.61	0.83
$Al_2(SO_4)_3 \cdot 18\ H_2O$	1.29	0.83
Limestone, $CaCO_3$	0.58	0.83

Source: Reference 10

Elemental Sulfur, S

Sulfur can be used for reclamation of calcareous alkali soils. The effectiveness of sulfur depends on the existence of sulfur-oxidizing bacteria (Thiobacillus) in the soil and the rate at which the oxidation process can take place. The following chemical reactions express the process of reclamation when sulfur is added to the soil:

(1) $2S+3O_2 \rightleftharpoons 2SO_3$ (microbial oxidation)

(2) $SO_3+H_2O \rightleftharpoons H_2SO_4$

(3) $H_2SO_4+CaCO_3 \rightleftharpoons CaSO_4+CO_2+H_2O$

(4) $\Big]\begin{matrix}Na^+\\Na^+\end{matrix} + CaSo \rightleftharpoons \Big]\ Ca^{++} + Na\ SO$

Where $]$ in reaction (4) represents the soil adsorption complex.

The following reaction also takes place to a very limited extent when sulfur is added to the soil:

$$(5)\quad \left]\begin{matrix}Na^+\\ Na^+\end{matrix}\right. + CaCo_3 + CO_2{+}H_2O \rightleftharpoons \left]Ca^{++}\right. + 2NaHCO_3 \quad \text{(limited)}$$

Sulfuric Acid, H_2SO_4

Chemical reactions resulting from the addition of sulfuric acid are the same as (3), (4), and (5) above.

Lime-Sulfuric (Calcium Polysulfide) CaS_5

Lime-sulfur is also limited in use to calcareous soils and is dependent on bacterial oxidation for its effectiveness:

$$(1)\quad CaS_5 + 8O_2 + 4H_2O \rightleftharpoons CaSO_4 + 4H_2SO_4$$

$$(2)\quad H_2SO_4 + CaCO_3 \rightleftharpoons CaSO_4 + CO_2 + H_2O$$

$$(3)\quad \left]\begin{matrix}Na^+\\ Na^+\end{matrix}\right. + CaSO_4 \rightleftharpoons \left]Ca^{++}\right. + Na_2SO_4$$

$$(4)\quad \left]\begin{matrix}Na^+\\ Na^+\end{matrix}\right. + CaCO_3 + CO_2 + H_2O \rightleftharpoons \left]Ca^{++}\right. + 2NaHCO_3 \quad \text{(limited)}$$

Gypsum, $CaSO_4$

Gypsum can be used in calcareous and non-calcareous soils and reacts directly with the soil:

$$(1)\quad \left]\begin{matrix}Na^+\\ Na^+\end{matrix}\right. + CaSO_4 \rightleftharpoons \left]Ca^{++}\right. + Na_2SO_4$$

Iron Sulfate, $FeSO_4$, $7H_2O$

Iron sulfate hydrolyzes in the soil to sulfuric acid as follows:

$$(1)\quad FeSO_4 + H_2O \rightleftharpoons H_2SO_4 + FeO$$

Sulfuric acid then reacts with the soil to release sodium sulfate and sodium bicarbonate as described above.

Aluminum Sulfate, $Al_2(SO_4)_3 \cdot 18\ H_2O$

Aluminum sulfate also hydrolyzes to sulfuric acid in the soil:

$$(1) \quad Al_2(SO_4)_3 + 3H_2O \rightleftharpoons 3H_2SO_4 + Al_2O3$$

and subsequent reactions follow in the manner elaborated for sulfuric acid. The sulfate amendments are only effective in calcareous soils.

Limestone, $CaCO_3$

Limestone has been used in some non-calcareous alkali soils. The effectiveness of limestone on different soils varies according to the pH of the soil solution. The effect of limestone can be expressed by the following hydrolysis reaction although other possible reactions have also been suggested for this amendment.

$$\left]\begin{matrix}Na^+\\ Na^+\end{matrix}\right. + CaCo_3 + H_2O \rightleftharpoons \left]\begin{matrix}\\ \end{matrix}\right. Ca^{++} + 2Na^{++} + HCO_3 + OH$$

Most alkali soils including those in the Antelope Valley area contain an appreciable amount of lime. However, due to the limited solubility of lime in alkali soils it plays no significant role in reclaiming the soil.

C. WATER AND SOIL SAMPLING AND ANALYSIS

In order to evaluate the suitability of available water supplies for reclamation and irrigation, and to determine the nature and extent of the salinity problem in the project area a program of water and soil sampling and analysis was undertaken. The method of water and soil sampling and the results of the analyses are presented in this chapter.

1. Water Sampling and Analysis

Water samples were collected from four sources: Oxidation Pond No. 3 (secondary treated effluent), tertiary treated effluent, sludge from tertiary treatment, and a well at the site of the Sanitation District No. 14 Sewage Treatment Facilities in

Lancaster. These samples were analyzed to determine pH, electrical conductivity, concentration of boron, concentration of cations: Ca^{++}, Mg^{++}, Na^{+}, and K^{+}, and anions: HCO_3^{-}, CO_3^{--}, SO_4^{--}, and Cl^{-}. The results of these tests are presented in Table 24. From these results it can be observed that the sodium percentage is very high in all of these waters, but that the total concentration of dissolved solids is relatively low. The analyses show that secondary and tertiary treated waters have a similar composition of cations but that the concentration of sulfate is higher in the tertiary water and also that it is more acid than the secondary treated effluent. These differences in water characteristics can be explained by the fact that alum is added to the secondary effluent during the tertiary treatment process. The sludge from tertiary treatment was analyzed to study its value as a leaching and soil amending agent.

Results of the analysis show no substantial difference between the sludge and the tertiary treated effluent. The lack of balance between the sum of cations and anions for all samples can be attributed to other constituents in these waters, nitrates, for example. Boron concentration in all four samples is fairly low and may not present any problem except for very sensitive crops.

In general, all of these waters are of fair quality, except for the high sodium percentage. In classifying these waters on the basis of total dissolved solids, sodium percentage, boron, and chloride concentration, (Reference 16) it can be stated that the low concentration of dissolved solids places them in class 1; high sodium percentage reduces them to class 3 waters; and medium boron and chloride concentration classifies them as medium or class 2 waters. In order not to overrate or condemn these waters on the basis of any one of the above factors, the combined effect of all the related parameters should be taken into account in their classification. Having these factors in mind, these waters could be called class 2 waters. These results indicate that tertiary treated water is suitable for the purpose of soil reclamation and irrigation of plants in the project area.

TABLE 24

CHEMICAL ANALYSES OF AVAILABLE WATER

SECONDARY TREATED EFFLUENT
(Oxidation Pond No. 3)

EC x 10^6 @ 25°C = 800 µmhos/cm

pH = 8.9

Boron = .65 ppm

Sodium percentage = 77

Cations		**Anions**	
Ca^{++}	.88 meq/l	HCO_3^-	4.2 meq/l
Mg^{++}	.44		
Na^+	6.52	$SO_4^=$	1.38
K^+	.57	Cl^-	2.12
SUM	8.41	SUM	7.70

TERTIARY TREATED EFFLUENT

EC x 10^6 @ 25°C = 846 µmhos/cm

pH = 6.6

Boron = .55 ppm

Sodium Percentage = 79

Cations		**Anions**	
Ca^{++}	.94 meq/l	HCO_3^-	1.6 meq/l
Mg^{++}	.42		
Na^+	6.86	$SO_4^=$	2.87
K^+	.45	Cl^-	2.41
SUM	8.67	SUM	6.88

TABLE 24 (Cont'd)

SLUDGE FROM TERTIARY TREATMENT

EC x 10^6 @ 25°C = 844 µmhos/cm
pH = 6.2
Boron = .65 ppm
Sodium percentage = 79

Cations		Anions	
Ca^{++}	.90 meq/l	HCO_3^-	1.58 meq/l
Mg^{++}	.30	$SO_4^=$	3.04
Na^+	6.52		
K^+	.51	Cl^-	2.22
SUM	8.23	SUM	6.84

WELL WATER

EC x 10^6 = 307.5 µmhos/cm
pH = 8.35
Boron = .135 ppm
Sodium percentage = 83

Cations		Anions	
Ca^{++}	.50 meq/l	HCO_3^-	1.7 meq/l
Mg^{++}	.12	$SO_4^=$	.34
Na^+	2.52		
K^+	.06	Cl^-	.51
SUM	3.20	SUM	2.55

2. Soil Sampling Program

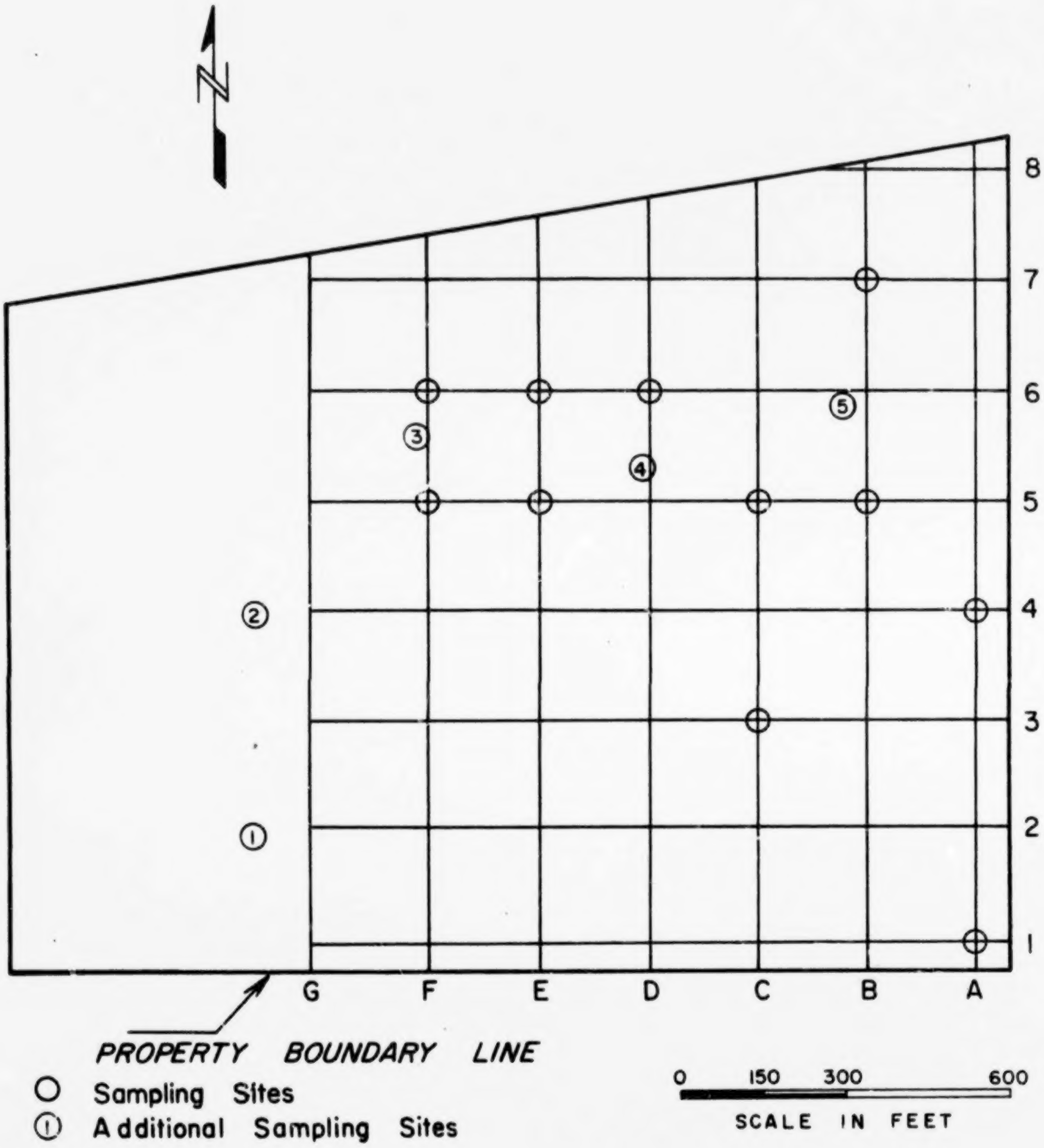
In order to evaluate the salinity condition in the project area, an extensive soil sampling program was planned and implemented. Because the soil condition in saline soils may vary considerably over a short distance, a 200 foot grid system was chosen and soil samples were collected at each grid point. A plan of the soil sampling grid system is shown in Figure 14. The first line of this grid system was 60 feet from the existing fence at the east side and next to the fence at the south side of the proposed park area. The depth of sampling trenches varied from five to 15 feet. This range of depth would be too great for an ordinary reclamation study. However, in the present project excavations will be made for two artificial lakes, extending to a depth of 12 feet below the present ground level. Knowledge of the soil stratification will permit spreading the better soils at the top and thereby accelerate the reclamation process. A minimum trench depth of five feet was chosen because this is the optium depth of agricultural soil for satisfactory growth of most ornamental trees.

Soil sampling was carried out by digging trenches to the required depth with a backhoe; then, a sample from each stratum was collected by scraping off the required amount from the side of the trench. In this manner an accurate survey was made of the entire area, and detailed field notes were taken as to the depth, color, texture, and structure of each stratum. The combined results of these samples yield detailed soil data for the project area. All of the trenches were filled after the conclusion of the sampling.

Some fifteen soil samples were collected from a tract of land outside the Sanitation District No. 14 Sewage Treatment Facilities, next to the west corner of the north fence. The purpose of this sampling was to study the similarity of the soil at this location to that of the project area and to determine the feasibility of conducting field tests in this area.

Study of Soil Stratification in the Project Area

Study of soil stratification reveals the nature of the soil layers at different depths and permits evaluation of their suitability for agricultural


N
8
7
6
5
4
3
2
1
G
F
E
D
C
B
A
①
②
③
④
⑤
PROPERTY BOUNDARY LINE
○ Sampling Sites
① Additional Sampling Sites
0
150
300
600
SCALE IN FEET

SOIL SAMPLING GRID SYSTEM AT THE PROPOSED PARK AREA

FIGURE 14

purposes. This study is based on the results of the soil survey which was carried out in July 1966 and October 1967 when soil samples were collected from the project area. From the observations made at some 50 locations in the proposed park area it can be stated that: 1) A shallow layer of top soil with an average depth of six inches exists in the project area. This layer has a brownish-gray or khaki color, a light texture, and is rather dispersed. 2) The subsoil is a gray or chalky, highly calcareous, compact loam or fine sandy loam of relatively high clay content, and has a depth of approximately 18 inches. 3) The substratum is a clay pan of brownish-gray or brown color and a depth of two to three feet. This layer is very compact and is highly impermeable to water. 4) Observations made at the deeper holes revealed that the clay pan is underlain by a sandy layer one to two feet deep, and sequence is repeated with a compact layer of sandy loam or loam, a sandy layer, and another layer of claypan. Observations made near the Sanitation District No. 14 Sewage Treatment Plant show that a similar condition prevails at that location. According to the United States Department of Agriculture classification these soils are of Pond loam series (Reference 15).

Agriculturally speaking claypan layers are of little or no value because they are highly compact and have a very low permeability. Top and subsoils can be improved by extensive cultivation and application of amending agents. Sandy layers can be mixed with other heavy textured layers to improve their permeability to downward and lateral flow of water.

Chemical Analysis of Soil Samples

Some 150 soil samples obtained from 45 locations at the proposed park area and from locations near the sewage treatment plant (taken from distinct soil layers at different depths) were analyzed for their chemical composition. These tests were carried out on the saturation extracts obtained from the soil samples and they encompassed the determination of the following components:

(1) Electrical conductivity

(2) Soluble Ca^{++}

(3) Soluble Mg^{++}

(4) Soluble Boron

(5) $CaCO_3$ (by effervescence)

(6) Soluble $Na^+ + K^+$ (by difference)

Representative results of these analyses are presented in Tables 25 and 26 for different soil strata at the park area and the plot near the sewage treatment plant.

Results of the soil analyses show that an acute saline-alkali situation exists at the proposed park area. This condition is aggravated by the existence of high boron concentrations in the entire soil profile. This high concentration of boron can be lowered to a safe limit for plant growth by extensive leaching of the soil.

Analysis of the soil samples obtained from the plot near the Sanitation District No. 14 Sewage Treatment Plant (where the pilot field studies were carried out) shows that a milder saline-alkali situation exists in that area. Boron concentrations are much lower in the soils of this region and did not present any problems after a moderate program of leaching was carried out.

Subsequent to the chemical analyses of the soil samples, gypsum requirement tests were carried out on a selected number of soil samples. These samples were chosen from the layers of soil that are suitable to form the topsoil of the proposed park area. The results of these tests show a variable gypsum requirement depending on the location and depth of the soil stratum. The gypsum requirement is between 4 to 52 tons per ac-ft. For the field application of gypsum an average application rate of 25 tons per ac-ft will be sufficient to supply the soil with needed Ca^{++} during the first phase of soil reclamation. Gypsum requirement for the soil near the sewage treatment plant has a range of 4 to 24 tons per ac-ft, and the average estimated demand is about 20 tons per ac-ft.

D. BENCH SCALE RECLAMATION EXPERIMENT

During the course of this project a bench scale reclamation experiment was conducted in the greenhouse to test the effectiveness of different amending agents and to

TABLE 25

REPRESENTATIVE RESULTS OF THE CHEMICAL ANALYSES OF SOIL SAMPLES OBTAINED FROM DIFFERENT DEPTHS AT THE PROPOSED PARK AREA

TOP SOIL (0 to 6 inches)

$EC \times 10^6$ @ 25°C = 5,700 µmhos/cm
Boron = 20 ppm
Ca^{++} = 1.4 meq/l
Mg^{++} = .5 "
$Na^+ + K^+$ = 55 "
Ca^{++} percentage = 2
$CaCO_3$ = very low

SUB SOIL (6 to 32 inches)

$EC \times 10^6$ @ 25°C = 25,000 µmhos/cm
Boron = 80 ppm
Ca^{++} = 1.2 meq/l
Mg^{++} = 1.2 "
$Na^+ + K^+$ = 249 "
Ca^{++} percentage = 0.5
$CaCO_3$ = moderate to high

CLAYPAN SUBSTRATUM (32 to 60 inches)

$EC \times 10^6$ @ 25°C = 30,000 µmhos/cm
Boron = 100 ppm
Ca^{++} = 1 meq/l
Mg^{++} = 0 "
$Na^+ + K^+$ = 299 "
Ca^{++} percentage = 0.3
$CaCO_3$ = moderate to high

TABLE 26
REPRESENTATIVE RESULTS OF THE CHEMICAL ANALYSES OF SOIL SAMPLES OBTAINED FROM A PLOT NEAR THE SANITATION DISTRICT NO. 14 SEWAGE TREATMENT FACILITIES

TOP SOIL (0 to 6 inches)

EC x 10^6 @ 25°C = 1,550 µmhos/cm
Boron = 1 ppm
Ca^{++} = 3 meq/l
Mg^{++} = 0.2 "
$Na^+ + K^+$ = 152 "
Ca^{++} percentage = 2.0
$CaCO_3$ = very low

SUB SOIL (6 to 38 inches)

EC x 10^6 @ 25°C = 7,000 µmhos/cm
Boron = 6 ppm
Ca^{++} = 1 meq/l
Mg^{++} = 0.2 "
$Na^+ + K^+$ = 69 "
Ca^{++} percentage = 1.5
$CaCO_3$ = low

CLAYPAN SUBSTRATUM (38 to 60 inches)

EC x 10^6 @ 25°C = 11,200 µmhos/cm
Boron = 2 ppm
Ca^{++} = 1.4 meq/l
Mg^{++} = 1.2 "
$Na^+ + K^+$ = 109 "
Ca^{++} = 0.9
$CaCO_3$ = high

obtain preliminary information on growth of plants under various methods of soil reclamation. These experiments were carried out at the University of California Antelope Valley Field Station in Lancaster. An agreement was made with the University to use their facilities for this experiment. Technical direction for the conduct of the experiment was provided by Engineering-Science, Inc. and the University of California bears no responsibility for these experiments or for the interpretation of the results.

1. Design and Implementation of the Greenhouse Experiment

The purpose of the greenhouse experiment was to test different reclamation procedures on a small scale and to determine the best method of soil reclamation applicable to the conditions of the project area. The choice of an amending agent for reclamation of a saline-alkali soil is dictated by the following factors:

(1) Amount of limestone in the soil.

(2) Period of time available for soil reclamation.

(3) Availability of amending agents in the area.

(4) Cost of amending agent and application.

If the soil is noncalcareous then such chemicals as sulfur, sulfuric acid, aluminum or iron sulfate should not be applied to the soil unless limestone is also added to provide calcium. When the time available for carrying out the soil reclamation is not limited such chemicals as sulfur, or lime-sulfur may be used successfully. But when soil reclamation must be completed in a matter of a few months then it is preferable to use gypsum or sulfuric acid for amendment. In the light of these considerations it was decided to use gypsum and sulfuric acid as amendments for the greenhouse experiment. The cost of gypsum is lowest among all of the chemical agents presented in Table 23. Commercial gypsum can be obtained approximately $80 per ton f.o.b. Sulfuric acid is the most expensive among the listed soil amendments and unless it is obtained in the form of liquid waste from an industry, it cannot be used for soil reclamation economically.

The experiment consisted of six treatments with replicates of three for each treatment. The list of these treatments is shown in Table 27.

TABLE 27

LIST OF DIFFERENT TREATMENTS FOR THE GREENHOUSE SOIL RECLAMATION EXPERIMENT

Amendment	Water Used for Leaching
No Treatment	Tap Water
No Treatment	Tertiary Treated Sewage
Full Gypsum Treatment	" " "
Half Gypsum Treatment	" " "
Full H_2SO_4 Treatment	" " "
Half H_2SO_4 Treatment	" " "

The experiment was set up by choosing 36 tin cans of 10 inches inside diameter and 14 inches height. A two-inch hole was made in the bottom of each can and it was covered with two layers of window screen and a layer of fiberglass to provide sufficient drainage for the soil. Sufficient soil was obtained from the top and subsoil of the project area and the pilot field area to fill the cans. The soil from each area was passed through a sieve with 1/4-inch square mesh and it was thoroughly mixed, separately. Each can was then filled with 45 lbs. of soil. Four samples were obtained from the sieved soil for each area and gypsum requirement tests were conducted on these samples. Based on the results of these tests the required amounts of gypsum and sulfuric acid were calculated (Reference 11) for the soil from each area.

Calculated values of different amending agents for the greenhouse experiment are shown in Table 28.

TABLE 28

CALCULATED VALUES OF AMENDING AGENTS FOR DIFFERENT SOIL RECLAMATION TREATMENTS

Treatment	Amount of Amending Agent Tons per Acre Foot	
	Project Area	Pilot Field
*Full gypsum treatment	13	11
Half gypsum treatment	6.5	5.5
+Full H_2SO_4 treatment	7.0	6.0
Half H_2SO_4 treatment	3.5	3.0

* Commercial $CaSO_4 \cdot 2H_2O$

+ 93.2% H_2SO_4

Cans were numbered and were randomly designated for different treatments. Half of the soil in each can designated for gypsum treatment was emptied and the calculated amount of commercial gypsum was thoroughly mixed with it. These cans were then refilled. Concentrated H_2SO_4 was poured at the top of the cans designated for H_2SO_4 treatment. Three liters of the proper water was then applied to each can. This first application was followed by two daily applications of two liters each during the following two days and one daily application of two liters per can thereafter. Drainage occured 36 hours after the first application and a composite sample from each three replicates was collected from the first leachate. Leaching was started on October 5th and was terminated on November 10th. During this period six composite samples were obtained from the leachate. These samples were analyzed in the laboratory to study the effect of different amending agents and the leaching practice on the soil adsorption complex. The results of these analyses are shown in Table 29.

From the results in Table 29 it can be concluded that the reclamation treatments were successful in completely replacing N^+ and K^+ ions adsorbed on the soil exchange complex by Ca^{++} and in lowering the boron concentration to a tolerable limit for plant life.

TABLE 29

RESULTS OF THE ANALYSES OF LEACHATE SAMPLES

Sample	$ECx10^6$ @ 25°C	Ca^{++} (meq/1)	Mg^{++} (meq/1)	(Na+K) meq/1 by difference	B (ppm)	(SAR+PAR)	Ca^{++} (Percent)
Project Area	Leachate collected after 7.8 inches of water was applied						
No Treatment Tap Water	19,000	17.3	6.7	166	100	48	9.0
No Treatment Treated Sewage	10,000	19.5	10.5	70	100	18	19.5
Full Gypsum Treatment	41,000	34.2	21.8	354	100	67	8.5
Half Gypsum Treatment	29,500	26.2	20.8	248	100	51	9.0
Full H_2SO_4 Treatment	44,000	54.0	*	*	100	*	12.5
Half H_2SO_4 Treatment	36,000	24.0	17	319	100	70	7.0
Pilot Field							
No Treatment Tap Water	7,850	19.3	1.7	57.5	5.5	18	25.0
No Treatment Treated Sewage	7,250	16.0	8.0	48.5	8.5	14	22.0
Full Gypsum Treatment	22,000	48.0	28.4	144.0	6.5	23	22.0
Half Gypsum Treatment	17,000	32.6	17.4	120	5.5	24	19.0
Full H_2SO_4 Treatment	33,500	60.2	*	*	23.5	*	18.0
Half H_2SO_4 Treatment	21,500	26.6	38.4	150	19	26	12.5

TABLE 29 (Cont'd)

Sample	$ECx10^6$ @ 25^oC	Ca^{++} (meq/1)	Mg^{++} (meq/1)	(Na+K)meq/1 by difference	B (ppm)	(SAR+PAR)	Ca^{++} (Percent)
		Leachate collected after 36 inches of water was applied					
Project Area							
N.T.T.	880	.4	.2	8.2	2.2	15	4.5
N.T.S.	1,250	.7	.1	11.7	2.0	18	6.0
F.G.	2,950	28.8	3.8	0	2.2	0	88.0
H.G.	2,950	29.8	2.6	0	2.6	0	92.0
F.S.	3,200	32.0	4.0	0	1.3	0	89.0
H.S.	2,850	28.2	3.4	0	1.6	0	89.0
Pilot Field							
N.T.T.	890	.32	.08	8.5	1.5	19	4.0
N.T.S.	1,240	.26	.22	11.9	1.5	25	2.0
F.G.	2,950	27.8	3.8	0	1.7	0	88.0
H.G.	2,550	22.8	2.8	0	1.6	0	89.0
F.S.	3,000	27.8	4.6	0	1.5	0	86.0
H.S.	2,800	24.8	5.2	0	1.3	0	83.0

SAR = Sodium Adsorption Ratio = $Na^{+}/\sqrt{(Ca^{++} + Mg^{++})/2}$

PAR = Potassium Adsorption Ration = $K^{+}/\sqrt{(Ca^{++} + Mg^{++})/2}$

*Result of the test was not meaningful for these situations.

Results of the analysis of leachate samples collected in the intermediate interval indicated that, had the concentration been lower initially, the leaching process could have been terminated after 28 inches of water was applied to each can. In order to further lower the boron concentration below the values recorded in Table 29, leaching was continued until 43 inches of water were applied to each can.

The results in Table 29 show that all four treatments with gypsum and sulfuric acid were equally successful in reclaiming the soil. The decision as to the choice of the amending agent for field application should therefore be based on the cost factor for each agent. Results of the analysis of leachate samples collected from the cans where no amending agent was added to the soil proves that a saline-alkali situation prevails in both areas and that leaching alone does not eliminate this problem. In fact, although the total concentration of cations in these cans is lowered at the end of the leaching treatment, the relative balance of these ions as demonstrated by sodium plus potassium adsorption ratio is either deteriorated or remains unimproved. Only in one case was this ratio lowered appreciably. This case cannot be explained satisfactorily and could be attributed to experimental errors.

2. Plant Growth Experiment

After the conclusion of soil reclamation experiment a greenhouse was built to conduct a plant growth experiment to further demonstrate the degree of effectiveness of different soil reclamation treatments. A 12 to 15 foot greenhouse was constructed by setting up a wooden frame and covering it by two layers of 0.6 inch polyethylene and a layer of 20-gauge mesh wire. A layer of wire was fastened to the frame and was then covered with polyethylene. Sufficient support was provided by nailing enough boards on the polythylene. A second layer of polyethylene was fastened to the interior of the frame to provide a better control of temperature and humidity in the greenhouse. A heater, a blower, and a fan were installed to control the temperature and humidity in the greenhouse and to provide for uniform mixing in the air. Pictures of the exterior and interior of the greenhouse are shown in Figure 15. The cans were planted with alfalfa on December 8, 1966. These cans were irrigated with tap water or treated sewage according to the experimental design.

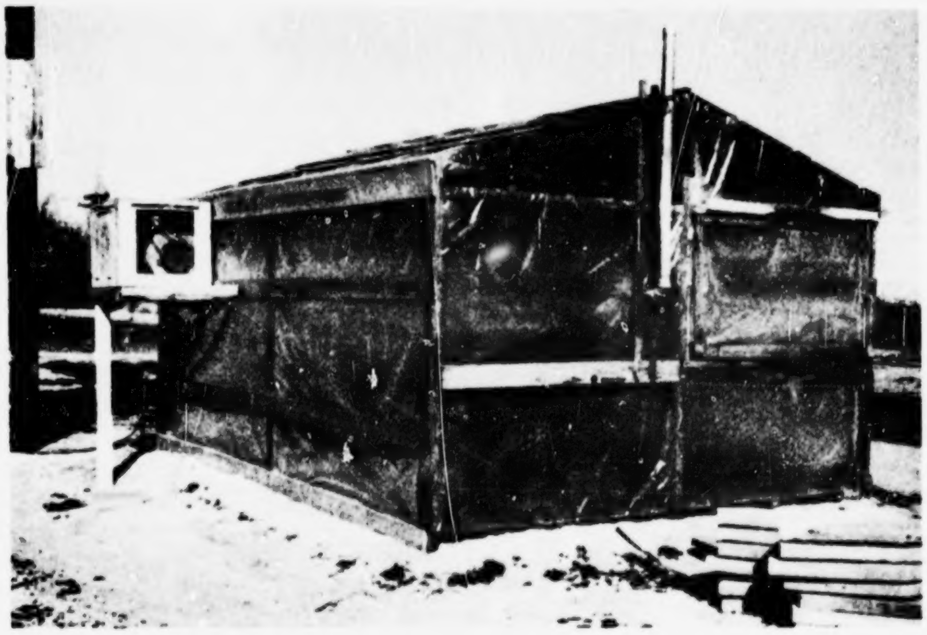
The purpose of the plant growth experiment was to study the effectiveness of different amending agents and treatment practices by growing alfalfa. Minimum allowable temperature in the greenhouse was set at 60°F. The plants germinated within a week of the planting date. Irrigation of plants was carried out according to the need of individual cans. Initially an excellent crop of alfalfa was standing in the cans with sulfuric acid treatment, growth in the cans with gypsum treatment was satisfactory, but cans with no treatment showed very slow growth. During the period of the experiment plants were supplied with N-K fertilizer and the greenhouse was fumigated to alleviate insect attack on the plants. This experiment was concluded on March 28, 1967 and photographs were taken from individual treatments. These photographs are shown in Figures 16 through 21.

3. Infiltration Rate and Hydraulic Conductivity Tests

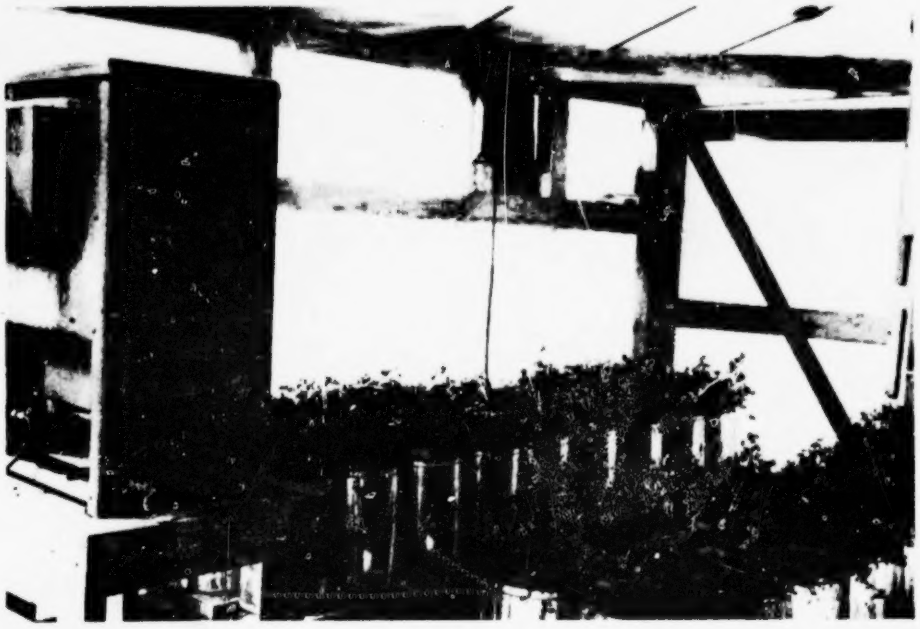
In order to study the degree of improvement in soil structure resulting from the reclamation and plant growth experiments two tests were conducted on the cans used for the greenhouse experiment to determine infiltration rate and hydraulic conductivity of the soils subjected to different treatments.

The infiltration test was conducted by using the ring infiltration technique. A ring infiltrometer is a cylindrical ring of 9 inches inside diameter and 12 inches length, which is inserted in the soil to a depth of about 6 inches; then water is added inside the cylinder and the rate of infiltration is measured by monitoring the water level in the cylinder with a hook gauge. When this test is continued for a prolonged period (several hours) the final value of infiltration rate represents a close estimate of the intake rate of the soil. The results of infiltration tests for different pots are presented in Table 30. These results indicate the favorable effect of the amending agents in improving the soil structure. It should be mentioned that infiltration tests are subject to numerous experimental errors and the general pattern of the indicated rates in Table 30 leads to more meaningful conclusions than the actual numerical values for the infiltration rates.

PICTURES OF THE GREENHOUSE FOR PLANT GROWTH EXPERIMENT

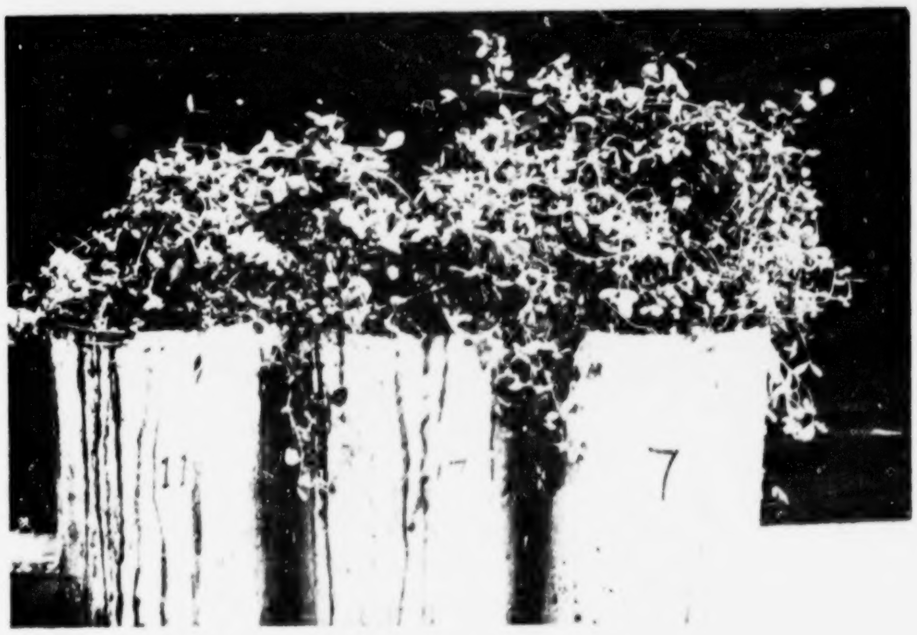


EXTERIOR

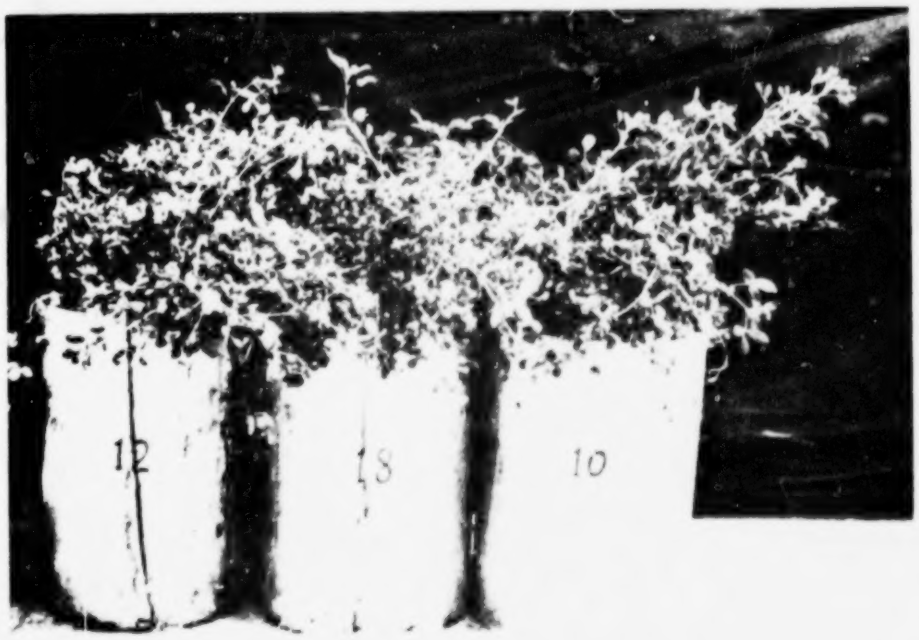


INTERIOR

FIGURE 15

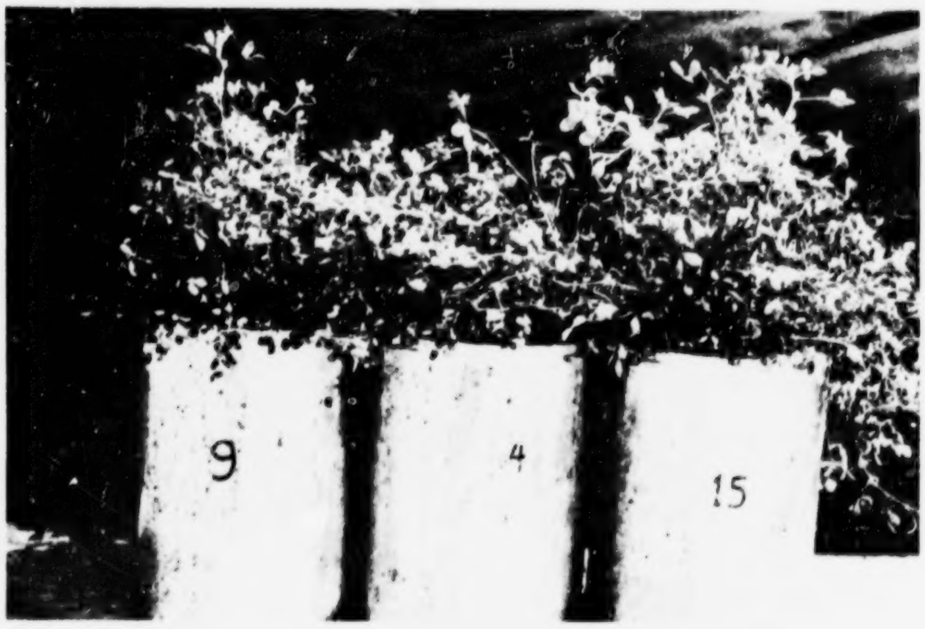


FULL H_2SO_4 TREATMENT

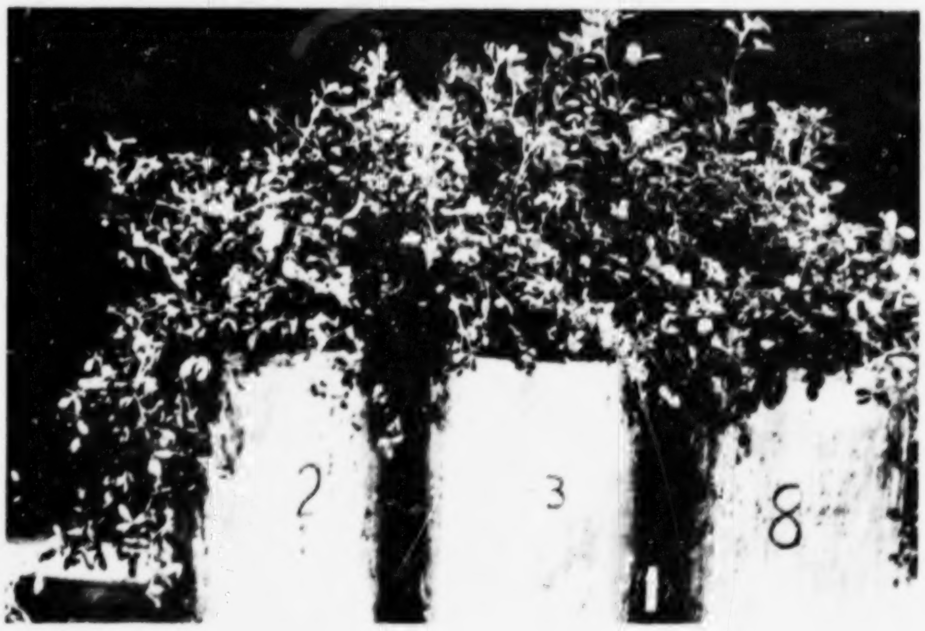


HALF H_2SO_4 TREATMENT

FIGURE 16

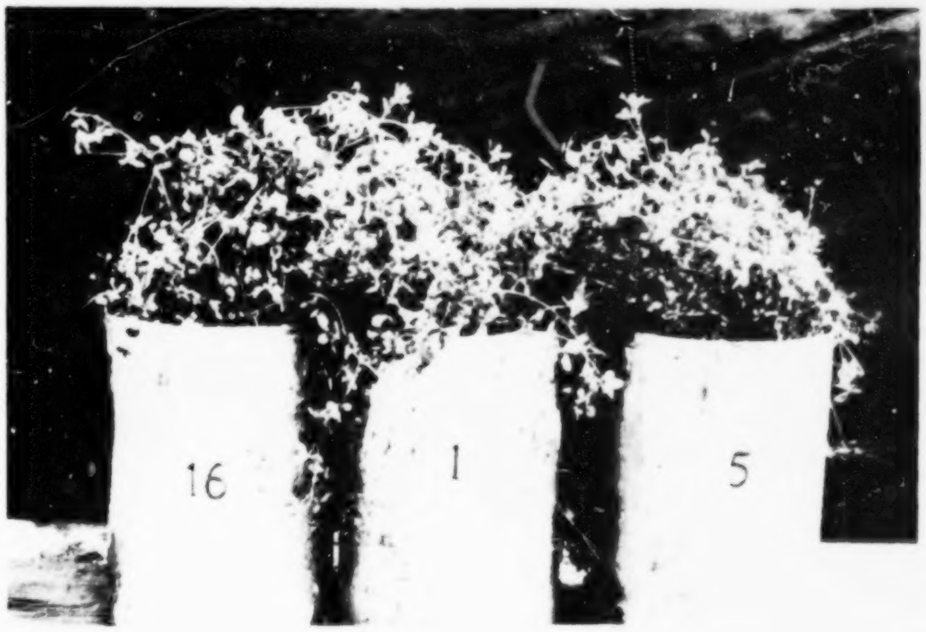


FULL GYPSUM TREATMENT

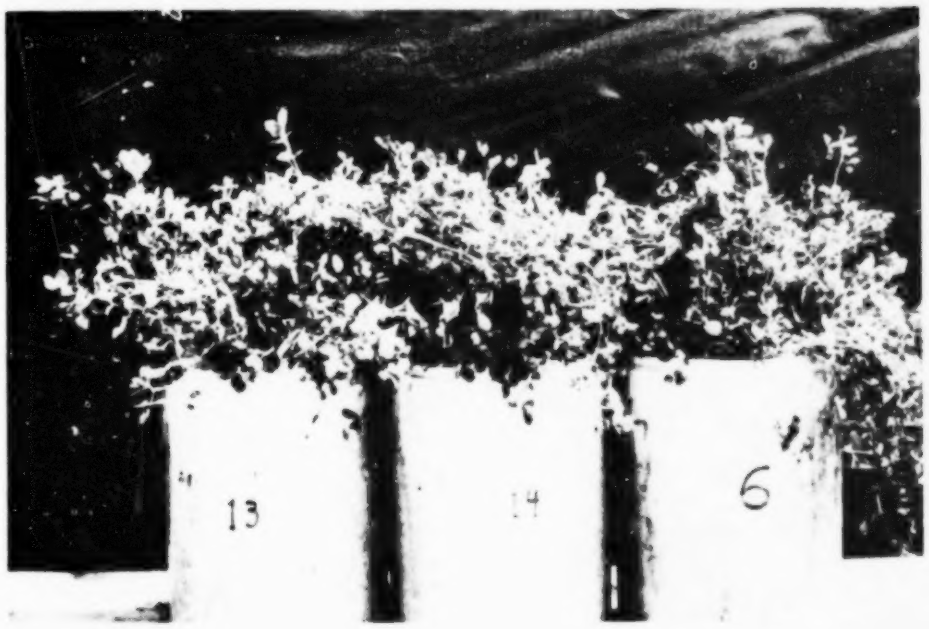


HALF GYPSUM TREATMENT

FIGURE 17



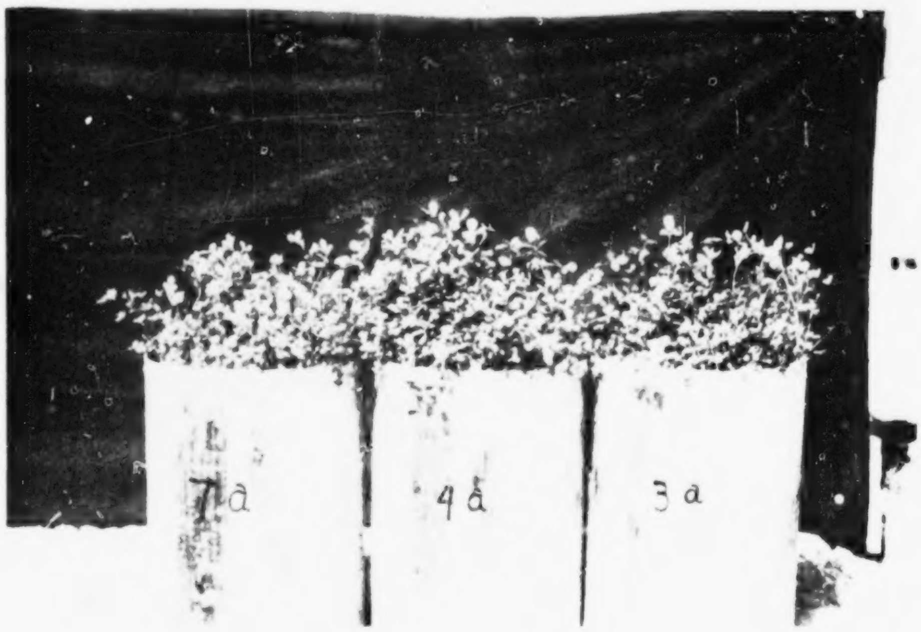
NO TREATMENT TREATED SEWAGE



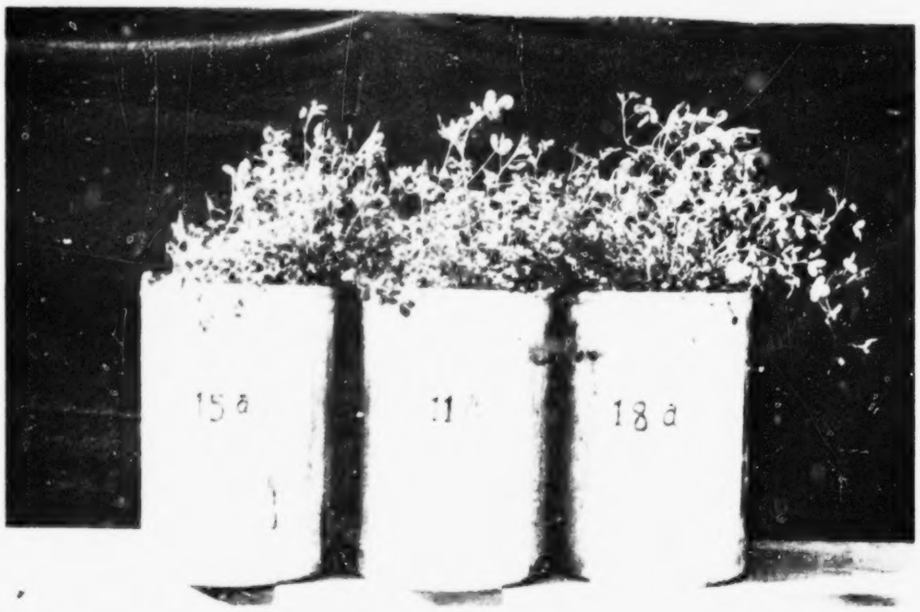
NO TREATMENT TAP WATER

FIGURE 18

Pilot Field Area

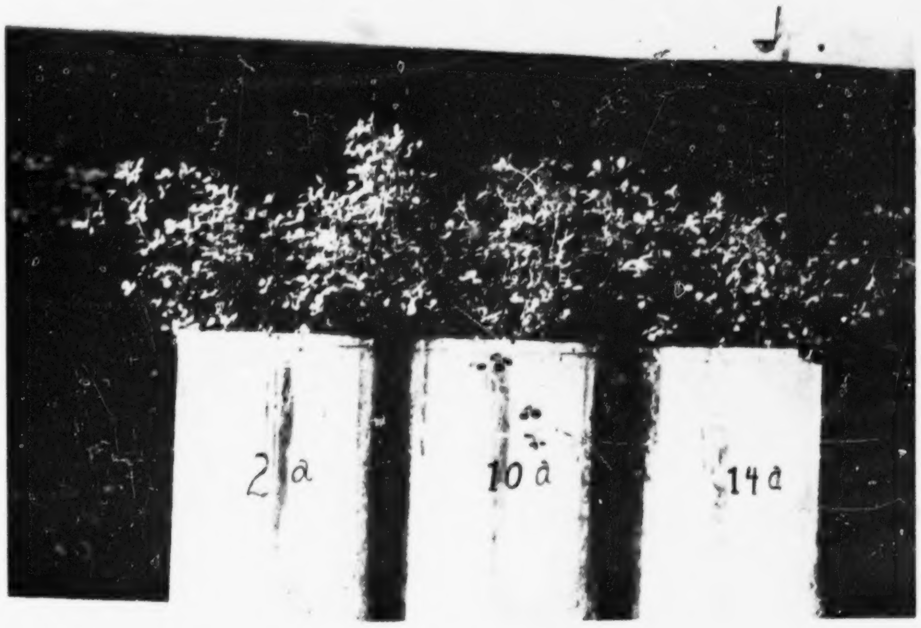


FULL H_2SO_4 TREATMENT

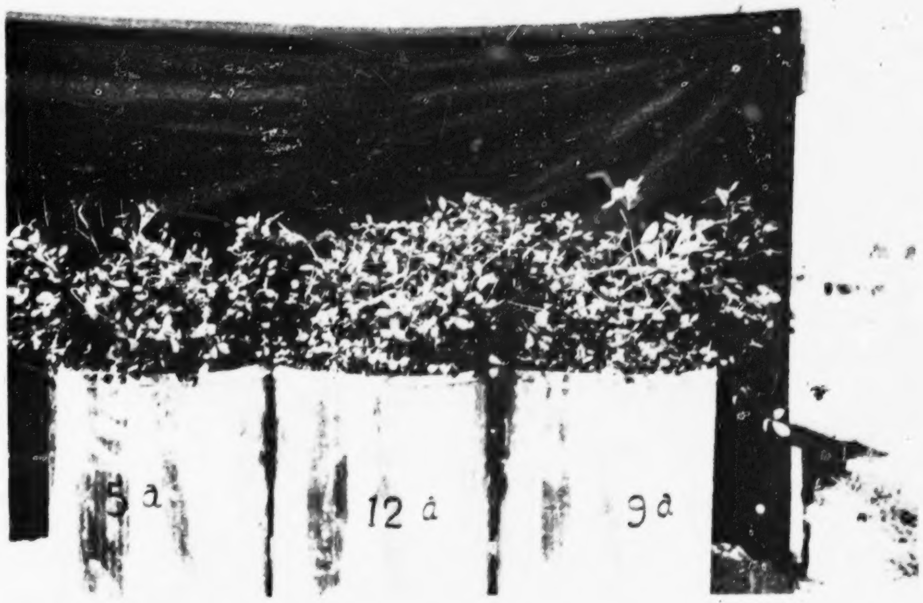


HALF H_2SO_4 TREATMENT

FIGURE 19

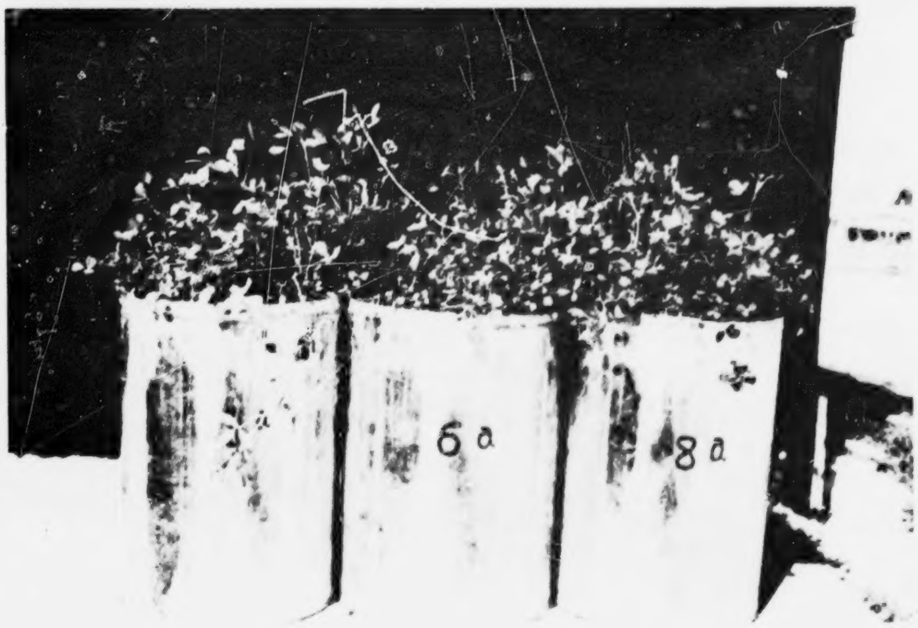


FULL GYPSUM TREATMENT

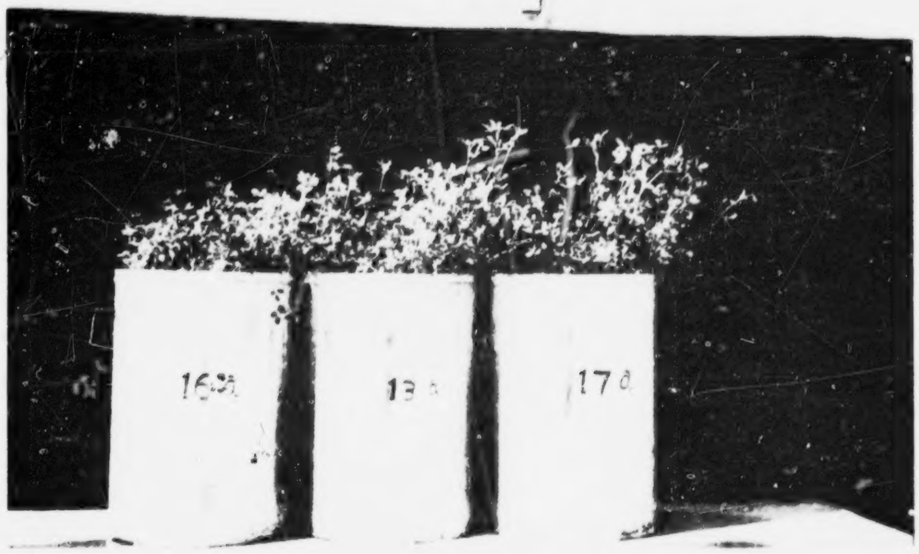


HALF GYPSUM TREATMENT

FIGURE 20



NO TREATMENT TREATED SEWAGE



NO TREATMENT TAP WATER

FIGURE 21

TABLE 30

RESULTS OF THE INFILTRATION TEST ON THE SOILS USED FOR THE GREENHOUSE EXPERIMENT

Treatment	Infiltration Rate-Inches per Hour	
	Project Area	Pilot Field Area
None (Tap Water)	.60	.20
None (Treated Sewage)	.40	.20
Full Gypsum	1.20	.50
Half Gypsum	1.10	.40
Full H_2SO_4	1.40	1.20
Half H_2SO_4	1.20	.80

TABLE 31

HYDRAULIC CONDUCTIVITY VALUES FOR SOIL SAMPLES FROM THE PROJECT AREA USED FOR THE GREENHOUSE EXPERIMENT

Treatment	Hydraulic Conductivity ft/day
No Treatment (leached with tap water)	.60
No Treatment (leached with tertiary treated effluent)	.62
Full Gypsum treatment *	1.16
Half Gypsum treatment	.88
Full Sulfuric acid treatment	1.75
Half Sulfuric acid treatment	1.38

*All other treatments were leached and were irrigated with tertiary treated effluent. Hydraulic conductivity tests were conducted with tap water.

A test was also conducted for determining the hydraulic conductivity of the soil samples from the project area which had been subjected to various reclamation treatments during the course of the greenhouse experiment. For this purpose six of the cans used in the greenhouse experiment were chosen and the rate of saturated flow, under a constant depth of water of two inches, through these cans was measured. Using Darcy's formula:

$$Q = KA\frac{dh}{dl}$$

$$\text{then} \quad K = \frac{Q}{A\,\frac{dh}{dl}}$$

The hydraulic conductivity, K, can be calculated from measurements of Q, A, and dh/dl. The results of the hydraulic conductivity test are summarized in Table 31.

These results also indicate the extensive improvement in the conductivity characteristics of the soil due to reclamation treatments. Superiority of sulfuric acid as an amending agent can be deduced from the fact that hydraulic conductivity of the soils subjected to acid treatment is, on the average, 50 percent greater than hydraulic conductivity values for the soils that were treated with gypsum.

4. Analysis of the results

After the initial slow growth of alfalfa in the cans with no treatment, these plants manifested a strong growth and eventually attained a similar state of growth with the plants in other cans. The slow start in the nontreated cans can be attributed to the unfavorable soil condition for germination and growth of young plants. The reason for the lack of any appreciable difference between the growth of the plants in the treated and untreated soils at the conclusion of the experiment can be explained by considering the following two factors. First, alfalfa is a rather salt tolerant plant which can grow in soils with saturation extracts showing an electrical conductivity of 8-10 millimhos per centimer (Reference 14). Second, due to the extensive leaching operations and ideal drainage conditions, the bulk of the salts in the saline-alkali soils used for the greenhouse experiment was carried out of the soil so that the final leachate from the cans with no treatment showed an electrical conductivity of 1 millimhos per centimeter (Table 29). Considering these two factors it can be concluded that under these conditions no appreciable difference in the growth of alfalfa in different cans could have been expected. However, this does not indicate that leaching alone would suffice for reclaiming the saline-alkali soils in the project area. The results of the greenhouse experiment also indicate an appreciable degree of improvement in the soil structure and its tillability in the treated cans as compared to the soil in the cans. The improved soil structure in the treated cans was manifested by the granular form of the soil in these cans as compared to the dispersed soil in the untreated cans. Moreover, a definite difference in the rate of infiltration of water through the soils in the treated and untreated cans on the one hand and between different treatments on the other hand was exhibited during the irrigation of different cans. These components are also manifested by the results of infiltration and hydraulic conductivity tests shown in Tables 30 and 31.

E. PILOT FIELD RECLAMATION EXPERIMENT

In order to implement the results of the greenhouse experiment in the field and to obtain actual field data on the degree of effectiveness of different reclamation methods and the state of growth of plants in the soil, a pilot field experiment was undertaken. This experiment was carried out on a plot of land near the Sanitation District No. 14 Sewage Treatment Facilities in Lancaster.

1. Design and Implementation of the Pilot Field Experiment

The objective of this experiment was to conduct a soil reclamation program in which the results of the greenhouse experiment were applied in the field. Because there was no appreciable difference between the half and full treatments in the greenhouse experiment, it was decided to expand the field experiment to include treatments in which one-fourth of the maximum required amending agent was added to the soil.

A plot of land of 6300 square feet was selected adjacent to the northwest fence of the Sanitation District No. 14 Sewage Treatment Facilities. This plot was plowed to a depth of one foot in two perpendicular directions. After leveling the land it was subdivided into 28 sections of 225 square feet each. Several soil samples were collected from different locations in the plot and gypsum requirement tests were conducted on these samples. The result of these tests indicated that on the average 20 tons of gypsum was required to reclaim an acre of the soil to a depth of one foot. The soil reclamation experiment was carried out according to the plan shown in Table 32.

There were four replicates for each treatment. Four plots were set up as controls with no amending agent added to the soil.

TABLE 32

LIST OF DIFFERENT TREATMENTS FOR SOIL RECLAMATION EXPERIMENT

Amending Agent	Treatment		
Gypsum	Full	Half	Quarter
Sulfuric Acid	Full	Half	Quarter

Gypsum was scattered on the soil and was then mixed with the top six inches of the soil by discing. Sulfuric acid was sprayed on the soil and water was immediately applied to the plot. Gypsum was applied at the rate of 200 lbs per 225 square feet and concentrated sulfuric acid was applied at the rate of 114 lbs per 225 square feet for full treatment. Water was supplied by laying a 6-inch pipe from the tertiary treatment plant to the experimental plot. All of the plots were irrigated by flooding on January 17 and 18, 1967.

The leaching program for the pilot field experiment was carried out during the months of February and March 1967. Although no sub-drains were provided for the field plot, the rate of infiltration of water in the plots treated with H_2SO_4 was greater than that for gypsum plots and much greater than the rate for the nontreated plots. A depth of 2 to 3 feet of water was passed through the soil during 7-8 weeks of leaching operation. The leaching operation was terminated at the end of February to allow the soil sufficient time to dry prior to planting operations. The advantage and necessity of treatment was clearly manifested at this stage when, due to the improved soil structure, the treated plots were ready for cultivation in a matter of a few days, whereas, it took three weeks before one could enter the untreated plots. Acid treatments showed better results in immediate improvement of the soil conditions than the gypsum treatments.

The field plot was prepared for planting and was planted with annual rye on March 30, 1967. The field was seeded at the rate of 60 lbs per acre and was immediately irrigated by sprinklers. The field was irrigated at two-day intervals for a period of 15-20 minutes to prevent it from crusting and to facilitate the germination of the seeds. The reason for choosing rye grass for the field experiment was that it has a shorter growth cycle than alfalfa and is more sensitive to salts. In this manner more information could be obtained as to the behavior of a different species under the field conditions prevailing in the experiment area.

Germination occurred in those plots treated with sulfuric acid in a few days. Plants in plots treated with gypsum were slower in germinating and exhibited little vitality. No germination occurred in the untreated plots. This lack of germination in the untreated plots is attributable to two factors: (1) toxicity effect of salts and boron, and (2) lack of soil aeration due to the waterlogged conditions existing in these plots.

Irrigation of the field was carried out by sprinkling twice weekly until May 15, 1967. Thereafter, the field was irrigated by flooding to facilitate the irrigation work and to apply a greater depth of water in a shorter period of time. Tertiary treated water was used for leaching and irrigating the pilot field. During the course of this experiment it was observed that the plots treated with sulfuric acid showed better growth than did the gypsum treated plots. Best growth was obtained with full sulfuric acid treatment; growth decreased with decreasing application of sulfuric acid. Gypsum treated plots exhibited inferior soil characteristics as compared to sulfuric acid treated plots. The state of growth in these plots manifested a direct relationship with the amount of the amending agent applied. On June 29th the field experiment was concluded and photographs were taken of each plot. These photographs are shown on pages 161 through 164.

2. Analysis of the Results

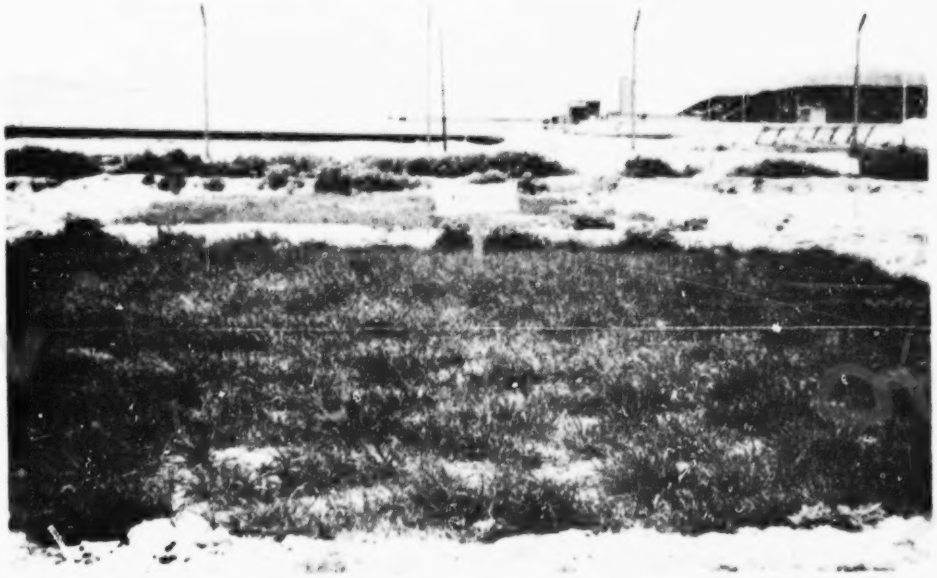
Results of the pilot field experiment clearly show the degree of effectiveness of various reclamation treatments. From the photographs it can be observed that the best degree of growth is attained by full sulfuric acid application. For this treatment the relative growth of plants decrease with decrease in the rate of application of the acid. The same argument is also true for gypsum treated plots. A comparison of gypsum treated with sulfuric acid treated plots shows that for the same level of application of the amendment, gypsum treated plots are slightly inferior to sulfuric acid treated plots. The difference between sulfuric acid and gypsum treated plots is partly due to the fact that because of limited leaching operations all of the applied gypsum was not brought into solution and therefore, it did not exert its full effect in reclaiming the soil. In field application if sufficient water is applied during the leaching operations to dissolve all of the applied gypsum no appreciable difference will be observed between gypsum and sulfuric acid treatments. Finally the untreated plot shows that addition of an amending agent is absolutely necessary for growing even salt tolerant plants in these soils.

F. RECOMMENDED PLANT SPECIES FOR THIS AREA

Climate limits the selection of plants that will grow satisfactorily on the high desert. This area is characterized by wide swings in temperature, both between summer and winter and between day and night. Winter lows of 6° to 0° have been recorded, however, from December through February the mean daily minimum usually ranged from 32° to 40°. High summer temperatures above 110° have been recorded. On the average, there are 110 days with temperatures above 90° and in the winter 80 to 85 nights with temperatures below 32°. Freezing nights are often followed by days of 60° mean

FULL GYPSUM

FULL GYPSUM TREATMENT

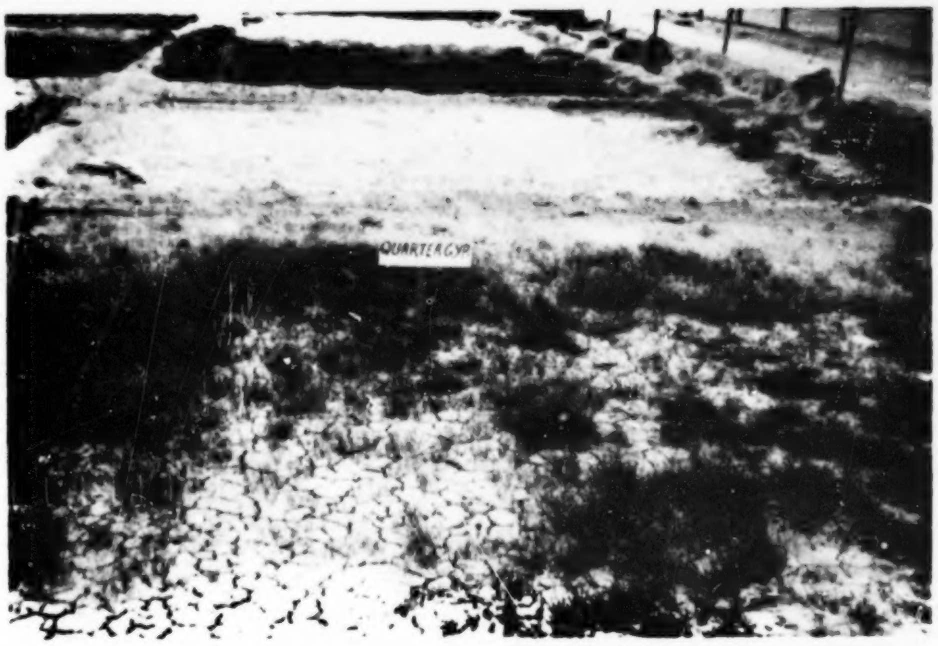


FULL H_2SO_4 TREATMENT

HALF GYPSUM

HALF GYPSUM TREATMENT

HALF H_2SO_4 TREATMENT


QUARTER GYP

QUARTER GYPSUM TREATMENT

QUARTER H_2SO_4 TREATMENT

NO TREATMENT

temperature. The plants selected must be adapted to these extremes in temperature.

The hazards of climate are the late spring frost and the desert winds. Wind protection, whether by natural terrain, windbreaks, or fences, will increase the chance of plant survival and the rate of plant growth. If winter soil moisture is not adequate, winter winds and bright sunlight may combine to kill normally hardy evergreen plants by desiccation.

Salinity and alkalinity are also important factors in choosing the suitable plant species for an area. The project area is a highly saline-alkali soil and must be reclaimed to a nearly normal soil before planting most trees and shrubs. Most grasses are more salt-tolerant than many of the ornamental plants, and can be started before reclamation is completed to the full depth of the soil profile.

All normal soils contain various salts. Salts are essential to the growth of plants. Saline soils contain an overabundance of salts, which in high concentration damages plants. Salts containing sodium or chloride are particularly injurious to ornamental plants.

Salinity generally causes stunting of plants. All plant parts--leaves, stem and fruit--are smaller than normal. The higher the salinity, the greater the stunting. Sodium chloride also can cause specific injury to certain plants. Many ornamentals develop leaf burn, leaf drop or stem dieback from sodium or chloride accumulation in the plant.

Salt injury is usually more severe during periods of hot, dry weather. High temperatures intensify leaf burn injury caused by chloride or sodium, and salt is likely to accumulate in the soil at an increasing rate during hot weather. Water loss from soil--through plant use and evaporation--is greatest during this period, and ordinary watering may not be sufficient to remove the salts by leaching below the rooting zone.

Information as to the salt tolerance of ornamentals is very limited and only isolated pieces of work are available on the subject--in contrast to the agricultural plants which are fairly well catalogued. In general, it is considered that most ornamental plants are sensitive to an appreciable amount of salt and some of the exceptions will be indicated in the following section pertaining to the various types of plants.

Salinity of the soil is measured in millimhos per centimeter of the saturation extract. Non-saline soils are usually below 2 millimhos, although many salt-sensitive plants, including ornamentals, will tolerate salinity up to about 4 millimhos per cm or slightly above. In gypsiferous soils, or where gypsum or sulfuric acid has been added as amendments, and is still present in the soil sample, readings for a given salinity are about 2 millimhos per cm higher than in its absence. Following is a list of recommended grass and ornamental trees for the proposed park area.

1. Grasses

In general, the grasses are medium salt-tolerant--4 to 8 millimhos per cm. The grasses are sown singly or as mixtures. Mixtures are usually sown in parks.

Bluegrass--Bluegrass, also known as Kentucky bluegrass, is available with several selections or strains, having only slight differences between them.

Fine Fescues--These are reportedly less particular about soil conditions than bluegrass; they are fairly drought-tolerant and will take some shade. Fine fescues should not be used alone--they get too clumpy, but mixed with bluegrass, they make a fine park lawn mixture.

Perennial Rye--This grass is a major constituent in inexpensive lawn grass mixes. It has a medium-coarse texture and tends to be rough and bunchy for a "perfect green carpet", but is is a very salt-tolerant grass.

Redtop--This is coarse in texture, quick growing and is usually used in mixes.

Coarse Fescues--These are wide-bladed, but tend to be clumpy. They are very tough and wear-resistant and useful on football fields or lawns that get rough treatment.

Grasses may be planted after a foot or 18 inches of the surface soil has been reclaimed. However, sufficient irrigation water should be applied above that required for evapotranspiration to provide some leaching downward, thus preventing the subsoil salt from moving upward into the surface soil.

2. Ornamental Trees and Shrubs

In general, trees and shrubs are sensitive to salinity and the soil should have an electrical conductivity of about 2 millimhos per cm or less. With gypsum in the soil, 4 millimhos per cm may be tolerated. Most trees and many shrubs are deep-rooted--six feet or more--and require reclamation in depth.

Following is a list of the suitable ornamental trees and shrubs for the park area. A few ornamentals, to varying degrees, are salt tolerant and where this information is known it will be listed under remarks or at the end of the list of plants.

The following abbreviations are used in this list: deciduous (D), evergreen (E), and height of plant in feet (ft) usually obtained under good growing conditions.

STREET AND SHADE TREES

Pinus helepensis (Aleppo pine) (E), 30-60 ft, moderately rapid growing, drought tolerant.

Fraxinus velutina (Arizona ash) (D), 50 ft, drought tolerant.

Fraxinus velutina (Modesto ash) (D), 50 ft.

Gleditsia tricanthos 'inermis' (thornless honey locust) (D), 35-70 ft, good hot summer desert plant.

Morus alba (white mulberry) (D), 20-60 ft, fast growing in hot climate, drought tolerant after established.

Albizia julibrissin (silk tree) (D), 40 ft, good desert plant.

PARK TREES AND SHRUBS

Betula nigra (birch) (D), 50-90 ft, requires ample soil moisture.

Betula verrucosa (birch) (D), 30-40 ft, requires ample soil moisture.

Betula verrucosa dalecarlica (D), requires ample soil moisture.

Cercidium floridium (Blue verde) (E), 25 ft, drought resistant.

Cotinus coggygria (Smoke tree) (D), 25 ft, especially good, in this area.

Crataegus (Hawthorn-Autumn Glory) (D), 25 ft.

Crataegus lavallei (D), 25 ft.

Crataegus oxyacantha (D), 18-25 ft.

Crataegus phaenopyrum (D), 25 ft.

Eucalyptus micratheca (E), 35-40 ft, fast growing, drought tolerant, no breakage from wind.

Eucalyptus macrandra (Marlock) (E), 25-35 ft.

Eucalyptus nicholii (leafed peppermint) (E), 40 ft.

Eucalyptus panciflora (Ghost Gum) (E), 40 ft, requires moist soil.

Eucalyptus stellulata (Black Sally) (E), 50 ft.

Heteromeles arbutifolia (Toyon) (E), 15-25 ft, drought tolerant.

Ilex altaclarensis (Wilson Holly) (E), 15-20 ft, takes wind, requires ample soil moisture and good drainage.

Juniperus chinensis (Hollywood juniper) (E), 20 ft, drought resistant.

Koelreuteria henryi (Chinese Flame tree) (D), 20-40 ft.

Koelreuteria paneculata (Goldenrain) (D), 20-30 ft, alkaline, drought and wind tolerant. Requires good soil moisture when young.

Magnolia grandiflora (Bull Bay) (E), 80 ft, poor in wind, sensitive to salts.

Magnolia grandiflora 'exoniensis' (E), 20-30 ft, one of the hardiest magnolias.

Mabis (flowering crabapple) (D)

Olea europaea (olive) (E), 25-30 ft, tolerates hot dry summers.

Pinus mugo mughus (pine) (E), 4-5 ft.

Pinus thunbergiana (Japanese black pine) (E), 100 ft, good in high desert.

Pistacia chenensis (Chinese pistache) (D), 60 ft, tolerates summer drought in deep soils.

Pittosorium tobira (E), 6-15 ft, fairly drought resistant.

Prunus blireiana (Flowering plum) (D), 25 ft.

Prunus caroliniana (Carolina laurel cherry) (E), 20 ft.

Prunus cerasifera atropurpurea (purple leaf plum) (D), 25-30 ft, fast growing.

Punica granatum (pomegranate) (D), alkaline tolerant, very heat tolerant, drought resistant when established.

Robinia pseudoacacia 'decaisneana' (pink flowering locust) (D), 40-50 ft, adapted to hot dry regions, fairly fast growing.

Sophora secundiflora (Texas Mt. Laurel), 25 ft, thrives in hot sun, needs some water.

TREES AND SHRUBS FOR WINDBREAKS

Calocedrus decurrens (incense cedar) (E), 75-90 ft, slow growing, usually drought resistant. Requires deep but infrequent irrigation when young.

Caragana arborescens (Siberian pea) (D), 20 ft, good desert plant, fast growing.

Cypressus glabra (Smooth Arizona cypress) (E), 40 ft, fast growing, usually drought resistant when established.

Elaeagnus angustifolia (Russian olive) (D), 40 ft, fast growing, heat and wind tolerant. Very hardy.

Juniperus scopulorum (Juniper) (E), 50 ft, resistant to wind, drought, and poor soil.

Juniperus virginiana (juniper) (E), 50 ft, resistant to wind, drought and poor soil.

Ligustrum japonium 'texanum' (Japanese waxleaf privet) (E), 5-9 ft.

Ligustrum lucidum (glossy privet) (E), 35-40 ft, somewhat drought resistant.

Lonicera tartarica (honeysuckle) (D).

Nerium oleander (oleander) (D), 8-12 ft, fast growing, drought resistant, good salt tolerance.

Pinus canariensis (Canary Island pine) (E), 80 ft, drought tolerant, good on high desert.

Pinus halepensis (see above under street and shade trees).

Pinus nigra (Austrian black pine) (E), 40 ft, slow growing, very hardy.

Populus nigra 'Ilatica' (Lombardy poplar) (D), 40-100 ft, fast growing.

Prunus carolininana (see above, park and shade trees).

Pyracantha coccinea (Firethorn) (E), 8-10 ft.

Pyracantha stribbling (E), 15 ft.

Pyracantha victory (E), 10 ft.

Robinia "Idaho' (locust) (D), 460 ft, adapted to dry hot climate.

Robinia pseudoacacia (black locust) (D), 75 ft.

Syringa vulgaris (common lilac) (D), 15-20 ft.

Tamarix aphylla (E), 30-50 ft, fast growing, very salt tolerant.

FAST GROWING PLANTS IN ADDITION TO THOSE LISTED ABOVE

Ailanthus altissima (tree of heaven) (D), 50 ft, drought tolerant.

Betula verrucosa (birch) (D), 30-40 ft, requires ample soil moisture.

Cortaderia selloana (pampus grass), 8 ft, drought and salinity tolerant.

Elaeagnus fruit landii (fruit land silverberry) (E), 6-12 ft, heat and wind tolerant.

Elaeagnus macrophylla 'Ebbingi' (E), 10-12 ft.

Elaeagnus pungens (E), 6-15 ft.

Eucalyptus gunii (cider gum) (E), 40-75 ft, drought tolerant. very hardy.

Eucalyptus niphophila (snow gum) (E), 20 ft, drought and wind tolerant, slow growing.

Forsythia intermedia (D), 8-10 ft.

Gleditsia triacanthas (honey locust) (D), 35-70 ft, good desert plant.

Phyllostachys aurea (golden bamboo), 10-20 ft, running,needs frequent watering but takes some drought.

Pinus coulteri (Coulter pine) (E), 30-80 ft, Resistant to heat, drought, wind. Good in high desert.

Platanus acenfolia (plane tree, sycamore) (D), 40-80 ft. Fast growing.

Platanus occidentalis (American sycamore) (D) 40-80 ft. Very hardy.

Platanus Wrightii (Arizona sycamore) (D), 80 ft.

Populus alba (white poplar) (D), 40-60 ft, good desert tree.

Populus fremontii (Fremont cottonwood) (D), 40-60 ft, good in desert and for windbreak.

The U. S. Salinity Laboratory has studied the salt tolerance of a few ornamental plants. The ones adapted to this region and their salt tolerance are as follows:

Oleander is very salt-tolerant. Though it may be stunted, it grows satisfactorily in soil having salinities up to ECx10^3.

Spreading juniper tolerates salinities up to about 8 $ECx10^3$.

Pyracantha, pittosporum tobira, xylosma, and Texas privet tolerate salinities up to 5 $ECx10^3$.

Viburnum suffers leaf burn and roses are killed when the salinity is greater than about 3 $ECx10^3$.

Noted in the above list are plants considered drought-tolerant. Some of these plants may be somewhat salt-tolerant. These plants should be located around the edge of the park or in areas difficult to water.

Because of the winds in Antelope Valley, plants for windbreaks have been listed. Many of these plants may be used for other purposes than windbreaks.

G. CONCLUSIONS AND RECOMMENDATIONS

1. Conclusions

The following conclusions may be drawn from the results of the project:

a. Soil reclamation of the project area is possible when an extensive leaching and amending program is undertaken.

b. Gypsum or sulfuric acid or a combination of the two should be used for soil amendment.

c. A system of tile or open ditch drains should be installed for the successful conduct of the reclamation program.

d. Oxidation Pond or Tertiary Treated water may be used for the leaching process.

Correspondence with the soils consultant suggests that secondary treated effluent can be used for leaching the soils and irrigating the park site without complications.

Presence of algae in the secondary treated effluent has the beneficial effect of providing needed organic material for improving the soil structure and providing nutrients for the plants. However, algae if present in excessive concentrations, may seal the pores in the soil and cause a slow-down in the leaching process.

2. Recommendations

Following recommendations are made with regard to various aspects of the reclamation project.

a. Composition of the Top Soil

Due to the fact that extensive excavations will be carried out for the proposed lakes in the project area an opportunity is presented for mixing different layers of the soil existing in this area. Except for layers of claypan that are not desirable in an agricultural soil all other strata can be used for forming the top soil for the proposed park area. However, if claypan material does not exceed 25 percent of the total excavation, soil separation can be avoided by mixing these soils uniformly and using the mixed material for the top soil.

b. Grading for Leaching Operations

Because of the need for extensive leaching of the soils in the project area, it is recommended that initially the top soil is spread uniformly around the lakes with zero slope in all directions. The depth of this layer can be determined by calculating the total volume of excavated materials from the lake sites. Amending and leaching operations should be carried out after the grading is completed.

c. Kind, Rate and Method of Application of Amending Agent

Commercial gypsum is recommended as the soil amending agent to be used in the proposed park area. The reason for this choice is that gypsum is the most economical amending agent that is commercially available on the market. At the time of preparation of this report commercial gypsum was available at the cost of $5.00 per ton. Commercial sulfuric acid, on the other hand, costs about $80 per ton. Because each ton of sulfuric acid is equivalent to 1.75 tons of gypsum for soil reclamation purposes (Table 23) it can be concluded that sulfuric acid is nine times as expensive as gypsum on an equivalent reclamation effect basis. Our investigation also shows that waste sulfuric acid cannot be obtained from refineries (where their liquid waste is rich with H_2SO_4) at a price comparable to that of gypsum.

The amount required of amending agents is determined by the nature of saline-alkali soil, the depth of soil that must be reclaimed and solubility of the amending agent in water. The recommended amount of gypsum for the project area is 25 tons per acre foot of the soil. Because the solubility of gypsum is 30 milli-equivalents per liter, 25 tons of gypsum should be dissolved in 7 acre feet of water. In other words, when 25 tons of gypsum is added to the top foot of the soil, it is desirable to apply at least 6 to 7 acre feet of water per acre to the soil before adding more gypsum. In such a case we can assume that the first foot of soil is reclaimed and that the second application of gypsum will be utilized for reclamation of the second foot and so on.

Several methods can be used for applying the soil amendment. A desirable method is to prepare gypsum saturated water and leach the soil with this water. However, this method requires the installation of rather sophisticated mixing tanks and needs continuous monitoring and supervision. A more practical method is to spread the specified amount of gypsum on the soil and mix it with the top six inches of the soil by discing or raking in two perpendicular directions. After a depth of 10 feet of water is leached through the soil, additional gypsum is applied to the soil and the leaching process will be repeated for the second foot, etc. until the entire depth of the top soil is reclaimed. Ten feet of water is recommended to ensure that most of the boron will be leached from the soil. The reclaimed soil can then be used for preparing the final landscaping of the proposed park area.

The minimum depth of soil that should be reclaimed depends on the species of plants that will be planted in the soil. Where grasses and shallow-rooted flowers are planted, only the surface part of the soil profile (12 to 18 inches in depth) need be reclaimed, but for trees and many shrubs reclamation of a deeper profile (5 to 6 feet in depth) is required. Because of the proposed landscaping for the park area it is imperative that reclamation process be carried out by grading the soil with zero slope in all directions. After the completion of soil reclamation the final grading can be implemented. As far as the depth of soil that should be reclaimed during the leaching operations is concerned, two alternatives can be suggested:

(1) If it is desired to have a uniform top soil of 5 to 6 feet depth free from sodium salts around the lake area, then the volume of soil for the proposed landscaping can be calculated on the basis of the above soil depth. This soil volume should be spread uniformly around the lakes with zero slope in all directions. This depth should then be reclaimed in the manner described above.

(2) It is also possible to reclaim a uniform depth of two feet of the top soil which will suffice for satisfactory growth of grasses and shallow rooted flowers. However, at spots where trees and deep rooted shrubs are to be planted, holes should be dug with a backhoe to at least 6 feet depth; the clay layers can be mixed with sandy layers, or if too much clay is present, it should be removed and replaced in part with a sandy soil. When replacing the soil in the hole, it should be thoroughly mixed with gypsum, at the rate of 25 tons per acre foot. The breaking up of the claypan and the addition of gypsum will greatly increase the drainage of the soil and its reclamation. This method will be satisfactory if the number of required holes is not numerous; however, if a considerable number of deep rooted trees are to be planted, it may be more economical to reclaim the entire depth of the top soil initially.

d. Method of Leaching and Required Depth of Water

The recommended method of leaching is by basin flooding. After grading operations are completed and gypsum is added to the soil and is mixed with it by discing, basins with 20-25 ft width and with a length varying with the width of the strip of land around the lake should be constructed by forming levees two to three feet high around these plots. Water is then added in each basin to a depth of 12 to 18 inches and is allowed to percolate through the soil. To prevent clogging of the soil (which reduces the rate of movement of water through the soil) it is advisable not to reapply any water to the same basin until two or three days after the water from the previous application has disappeared from the soil surface. After a depth of 7 to 10 feet of water is leached through the soil, samples should be obtained from the first two 6-inch layers of the soil and a test should be made for boron and other chemical constituents of the soil saturation extract as shown in Table 25. If these tests show that the desired improvement has been achieved, the leaching operation can be discontinued and additional gypsum can be added and disced into the soil for reclamation of the second foot of the soil profile and the same process will be continued. Due to the reclaiming effect of the leachate from the upper depth of the soil on the lower portions of the soil profile it is possible that after two to three applications of gypsum the gypsum requirement of the soil will be met and no additional gypsum will be needed. In order to evaluate the progress of the reclamation process, it is recommended that after the second application of gypsum soil samples are secured at 6-inch intervals from the entire unreclaimed portion of the soil profile and standard tests for boron, sodium, calcium, etc. are conducted on the saturation extract of these samples. The results of these tests provide the basis for determining the subsequent rates of application of gypsum and the required extent of leaching operations.

Due to capillary movement of water in the levees and subsequent evaporation of this water, extremely high concentrations of salts will be accumulated in the levees. Therefore during each application of gypsum care should be taken that the soil in the levees is spread over the basins and is mixed with gypsum by discing. This will require that new levees are built after each application of gypsum.

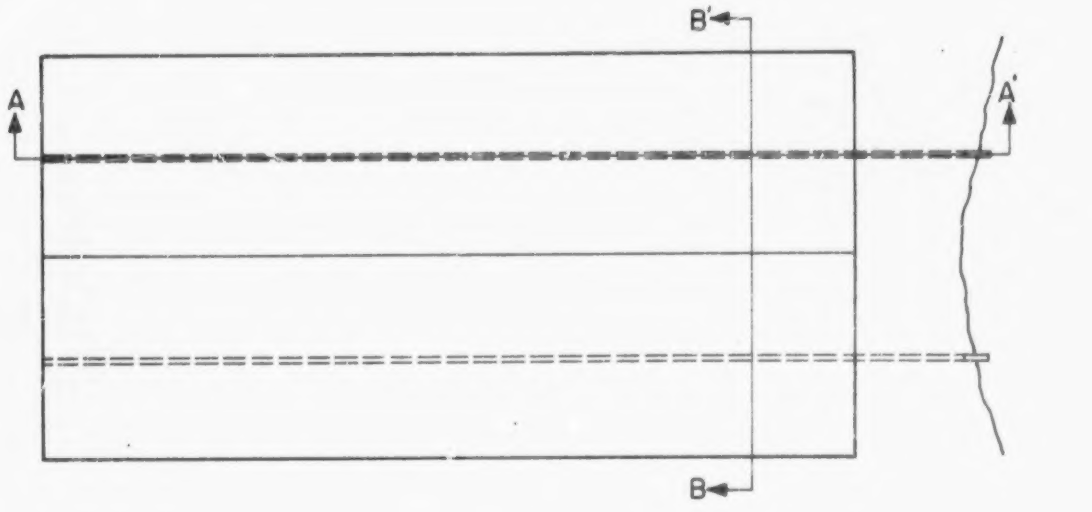
Due to the narrowness of the strips of land and the existence of the lakes which provide good natural drainage for leaching operations it is anticipated that no artificial drainage will be required. However if serious drainage problems develop during the course of the leaching operations it is suggested that six-inch tile drains are installed at 20 feet intervals at a depth of 4.5 or 5.5 feet from the surface for a soil depth of 5 or 6 feet respectively.

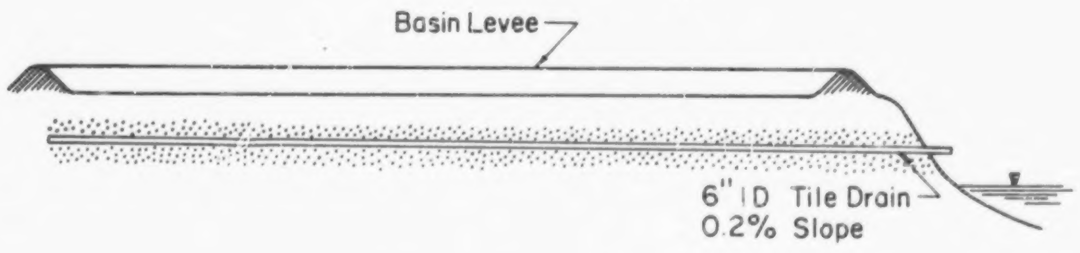
It is desirable that these tile drains are installed in the middle of each flooding basin in a direction perpendicular to the boundary of the project area with a slope of 0.2 percent and discharging into the lakes by gravity flow. For installation of the tile drains a trench can be excavated to the desired depth and the drain is laid in a gravel envelope. The trench is then backfilled with natural soil. Detailed design drawings of tile drains for a typical basin are shown in Figure 22.

e. Drainage Requirements for the Park Area

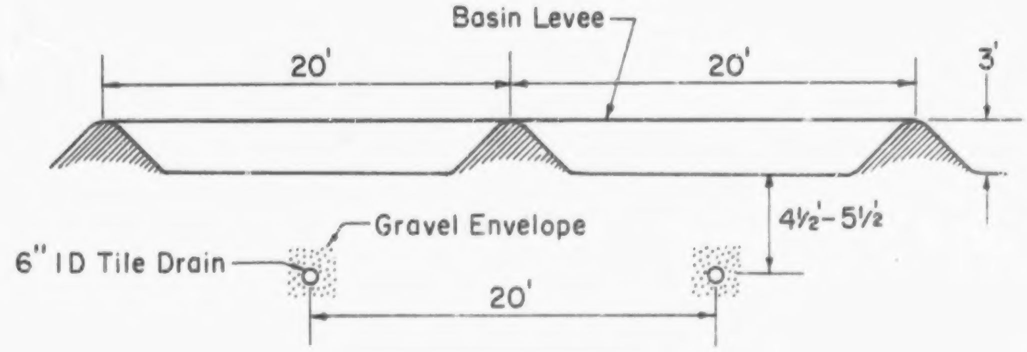
It is improbable that percolation of irrigation leachates into the lakes would be of such magnitude to impose serious water quality problems for plant life in the park area. Moreover, with availability of fresh supplies of tertiary treated effluent, it would seem undesirable to use the lake water for irrigation purposes which results in establishing a reuse cycle. However, a matter of more concern is the possibility of poor drainage on the leeward slopes of the topography around the lakes which may result in water logging around the perimeter of the park area. In order to provide a solution for this eventuality it is recommended that a 6-inch tile drain is installed along the 331 feet contour line at a depth of 3 feet below the ground surface between the two overflow structures along the south boundary of the project area. After a year or two of irrigation in the park area if serious problems develop in other parts of the park then the tile drainage system can be expanded to cover other sides of the project area. Figure 23 presents the design of a drainage outlet. In designing this drain outlet it was assumed that connection can be made at the proper elevation to the outflow structures for the lakes. Otherwise the drain outlets should be constructed independent from the overflow structures. In either case, the same surface drainage facility can be used for both leachates and the water overflowing from the lakes.

These recommendations were developed by considering the practical usefulness of each system as compared to the cost of installation and maintenance of that system. It is unnecessary to install an extensive




Basin Levee
6" ID Tile Drain
0.2% Slope

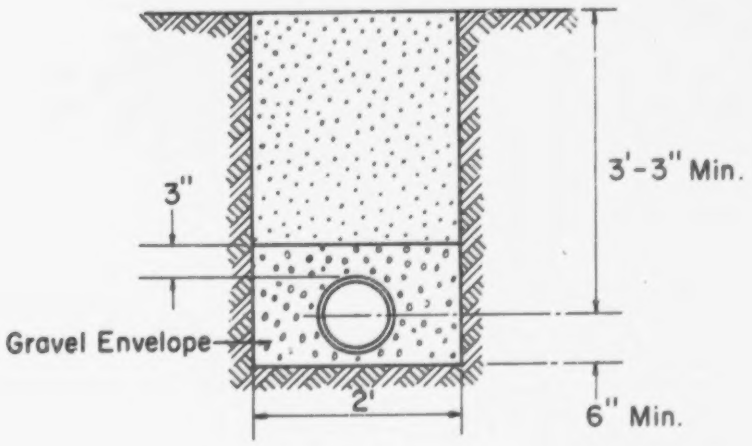
SECTION A-A'


Basin Levee
20'
20'
3'
4½'-5½'
Gravel Envelope
6" ID Tile Drain
20'

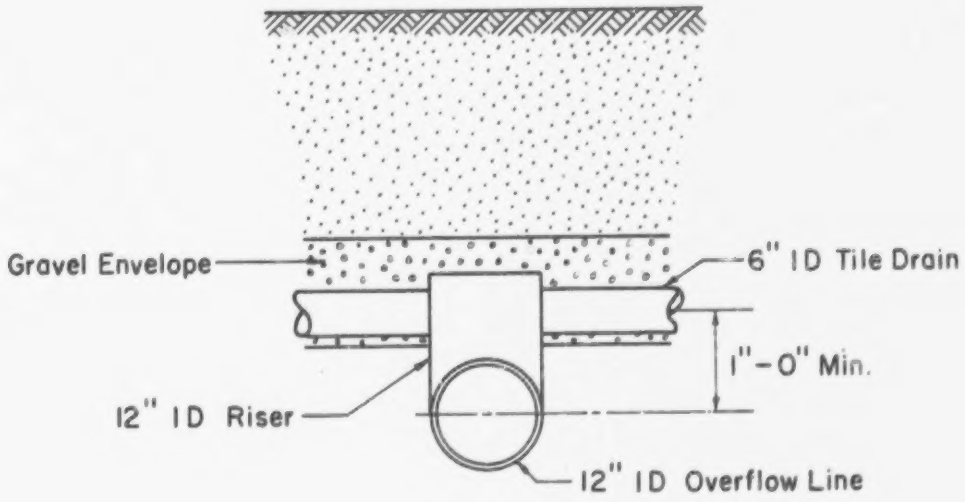
SECTION B-B'

DETAIL OF DRAINAGE SYSTEM FOR LEACHING BASINS

FIGURE 22


3'-3" Min.
3"
Gravel Envelope
2'
6" Min.

SECTION A-A


Gravel Envelope
6" ID Tile Drain
1"-0" Min.
12" ID Riser
12" ID Overflow Line

DETAIL OF TILE DRAIN
OUTLET JUNCTION

FIGURE 23

system of tile drains at great costs prior to establishing the need for such systems by prolonged field observations. It is probable that the leachates from reclamation operation and irrigation of the park area will percolate through the tight subsoil at a satisfactory rate in which case installation of any tile drain in the project area would be redundant. Results of the field experiment provide strong support for this hypothesis. However, in order to meet other eventualities the design of a drainage system was undertaken for this project.

f. Test for Determining the Degree of Soil Reclamation

It is recommended that during the course of leaching operations soil samples be secured from various depths of the soil at six-inch intervals and tests be conducted on the saturation extract of these samples to determine the degree of reclamation attained in the soil. These tests should include determination of such constituents as boron, calcium, magnesium, sodium, and potassium. The results of these tests will provide an indication of the degree of reclamation attained in the soil. These results should be compared with the limits specified for these constituents in this report to determine whether sufficient leaching has been carried out.

g. Irrigation of Plants in the Proposed Park Area

After completion of the soil reclamation program the park area can be graded for final landscaping and grasses and ornamental bushes and trees can be planted. At this stage it is necessary to take two precautions to maintain the salt concentration in the top soil at a level that will not be detrimental to plant life and that does not deteriorate the soil structure. These steps are as follows:

(1) When calculating the depth of irrigation water care should be taken that sufficient water is applied to meet the consumptive use of plants and to leach the soil in the root zone area of plants. This action will prevent the excessive buildup of salt concentrations in the root zone. Leaching requirement of the soil can be calculated from the following formula (Reference 14):

$$LR = \frac{D_{dw}}{D_{iw}} = \frac{EC_{iw}}{EC_{dw}}$$

where LR = leaching requirement

D_{dw} = depth of drainage water

D_{iw} = depth of irrigation water

EC_{iw} = electrical conductivity of irrigation water in millimhos per centimeter

EC_{dw} = electrical conductivity of drainage water

Tertiary treated effluent has an electrical conductivity of .85 millimhos per cm (Table 24) assuming that EC_{dw} = 2 millimhos per cm, then

$$LR = \frac{.85}{2} = .43$$

therefore $D_{dw} = .43\ D_{iw}$

In other words, if a given depth of water is required to sustain plant life for a certain period, then this depth should be increased by 43 percent to provide for leaching of salts from the root zone. Assuming a consumptive use of .3 inches per day for plants in the project area and an irrigation interval of five days, then total consumptive use for the five day period is 1.5 inches; if this depth is increased by 43 percent to account for the leaching requirement then:

$$D_{iw} = 2.1 \text{ inches}$$

Assuming that the irrigation system is 60 percent efficient,

$$D_{iw} = \frac{2.1}{.6} = 3.5 \text{ inches}$$

Therefore if a depth of 3.5 inches of water is applied at five-day intervals, then it can be assumed that both the consumptive use of plants and leaching requirement of the soil are satisfied. These figures are presented as a numerical example and do not necessarily represent the optimum frequency and depth of irrigation for the project area.

(2) Due to accumulation of salts in the soil as the result of evapotranspiration and considering the fact that the entire subsoil is and will remain saline-alkali, it is recommended that each year a light application of gypsum (5 tons per acre) is sprayed on the soil or dissolved in the irrigation water used in the park area. This practice will prevent the reversal of the reclamation process and will insure the development of a good agricultural soil in the proposed park area.

H. SIGNIFICANT PROBLEMS

During the course of the soils investigation it was discovered that the natural soil at the proposed park site has very high concentrations of boron and salts. In addition, the underlying layers of soil contain considerable amounts of impermeable clay.

Disposal of leachate in such a manner so as not to contaminate lake water and the newly rejuvenated soil must be carefully planned. Likewise, the spray irrigation of the landscaped park must be monitored so that salts and boron do not again rise to the surface via capillary action.

Perhaps the most significant problem is that soil reclamation is absolutely necessary for growing even boron and salt tolerant plants in these soils.

PART VII

POTENTIAL USES FOR RECLAIMED WATER

A. GENERAL

One of the initial project objectives was to demonstrate that renovated waste waters could be economically used for activities not expressly requiring potable water. Suggested uses for treated water include: water associated recreational facilities; certain industrial processes; soil reclamation; farm land irrigation; and irrigation of large grass areas such as public parks and golf courses.

In water short regions characterized by the Antelope Valley, it is imperative to develop all potential sources of water. The graph on the following page depicts the drastic reduction of the natural water table elevation. On the same page the average annual rainfall is graphed for the past 26 years. These two graphs clearly illustrate the need to conserve existing supplies for domestic purposes. In order for the area to continue developing at a rapid pace, water will need to be imported and/or reused.

Presently, an average of three million gallons per day of waste water is generated in the Lancaster area. Graphs on the following pages show projected population growth and corresponding sewage discharge. From the expected sewage flow, anticipated quantities of treated water can be calculated.

B. WATER ASSOCIATED RECREATIONAL FACILITIES

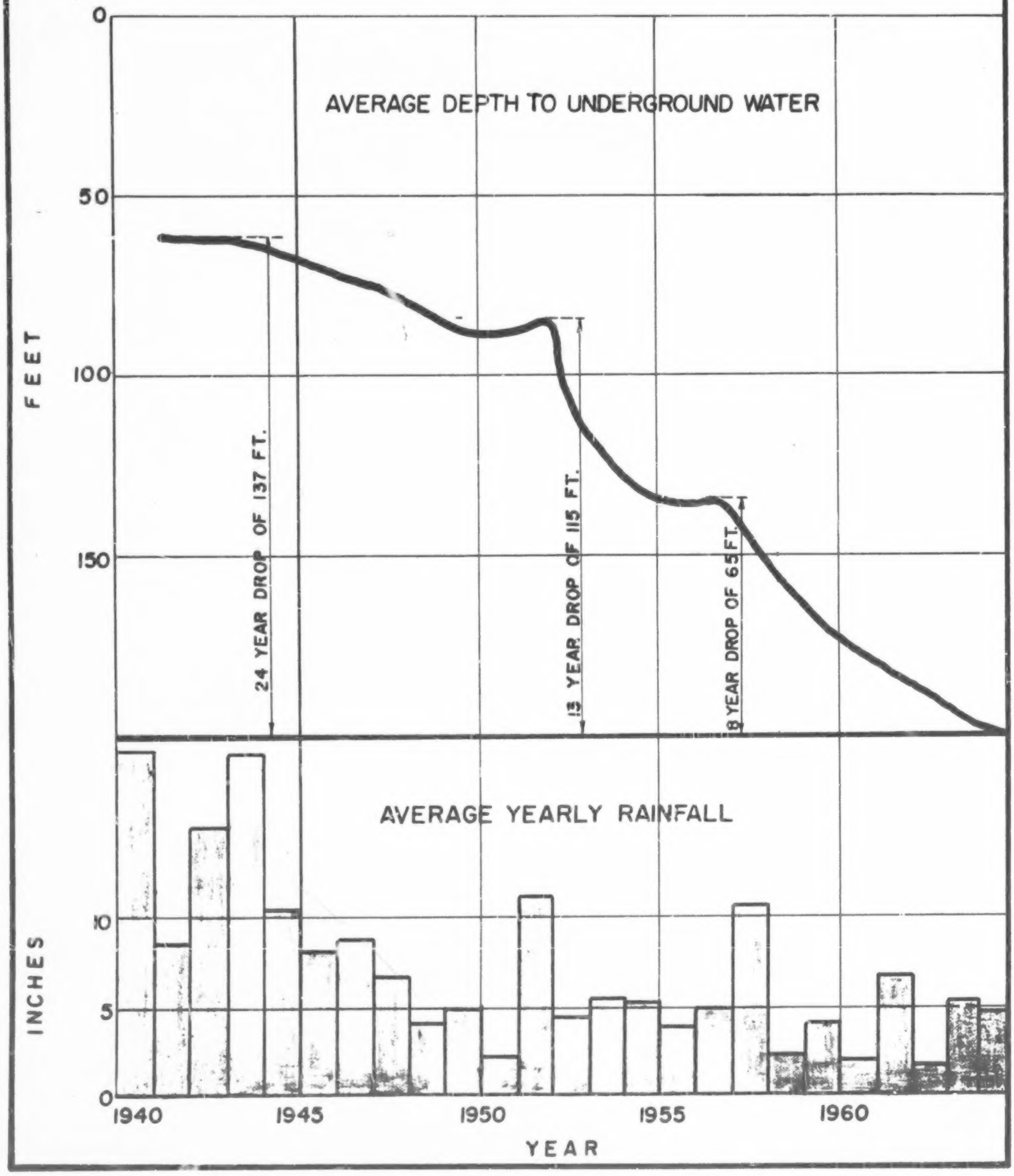
People living in the Antelope Valley area do not have readily available water related recreational activities; further population increases in this region will intensify such demands. It is very unlikely, however, that existing potable water supplies can be justified for such purposes. In fact, it is the policy of Los Angeles County Water Works District No. 4 to discourage uses of natural supplies for recreational uses.

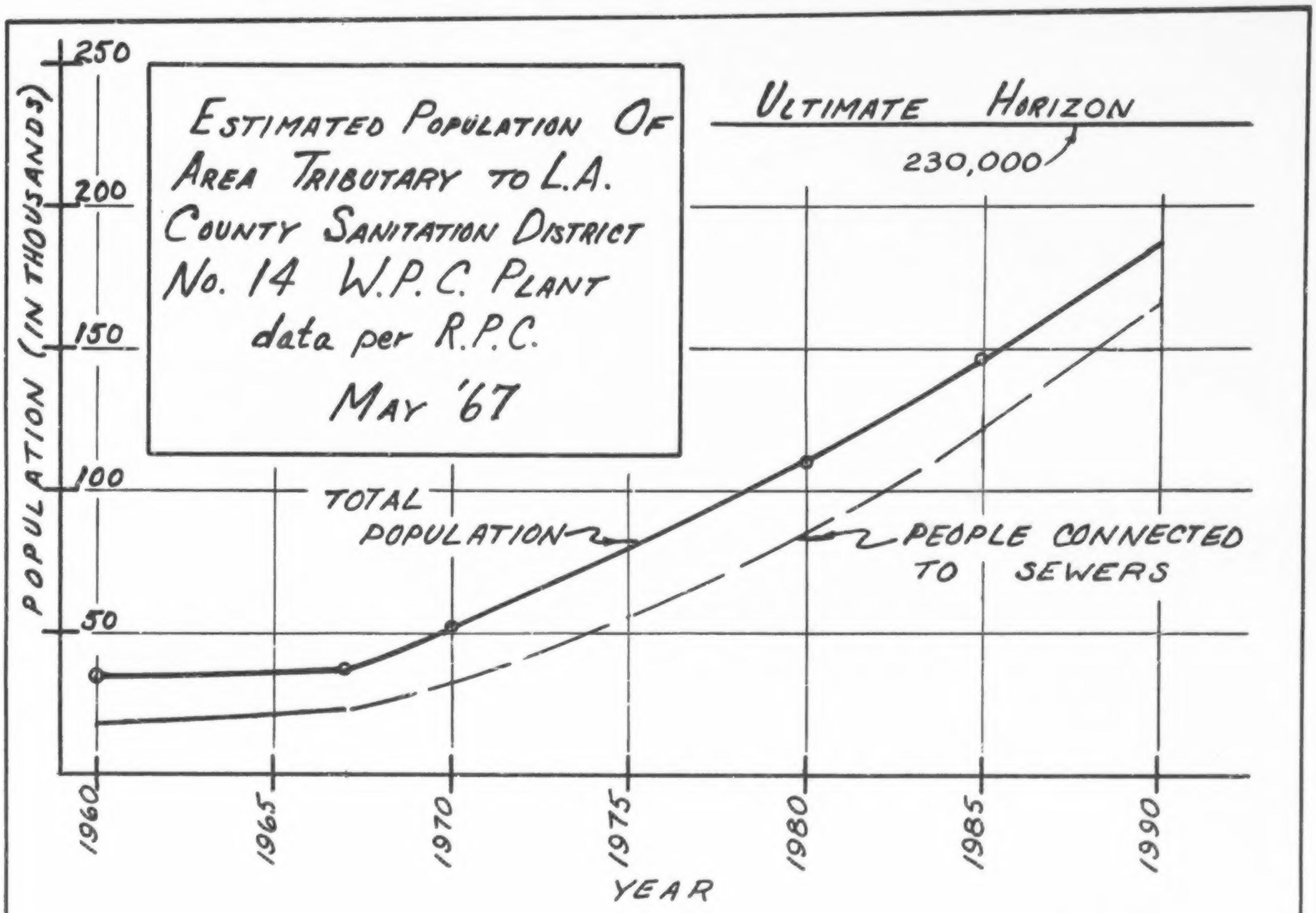
In view of the growing need for water related sports facilities, Los Angeles County is attempting to provide facilities through an aquatic park. A chain of three lakes, filled with polished renovated waste water, is envisioned as focal point of a 56 acre park in the

STATIC GROUND WATER LEVEL AND YEARLY RAINFALL

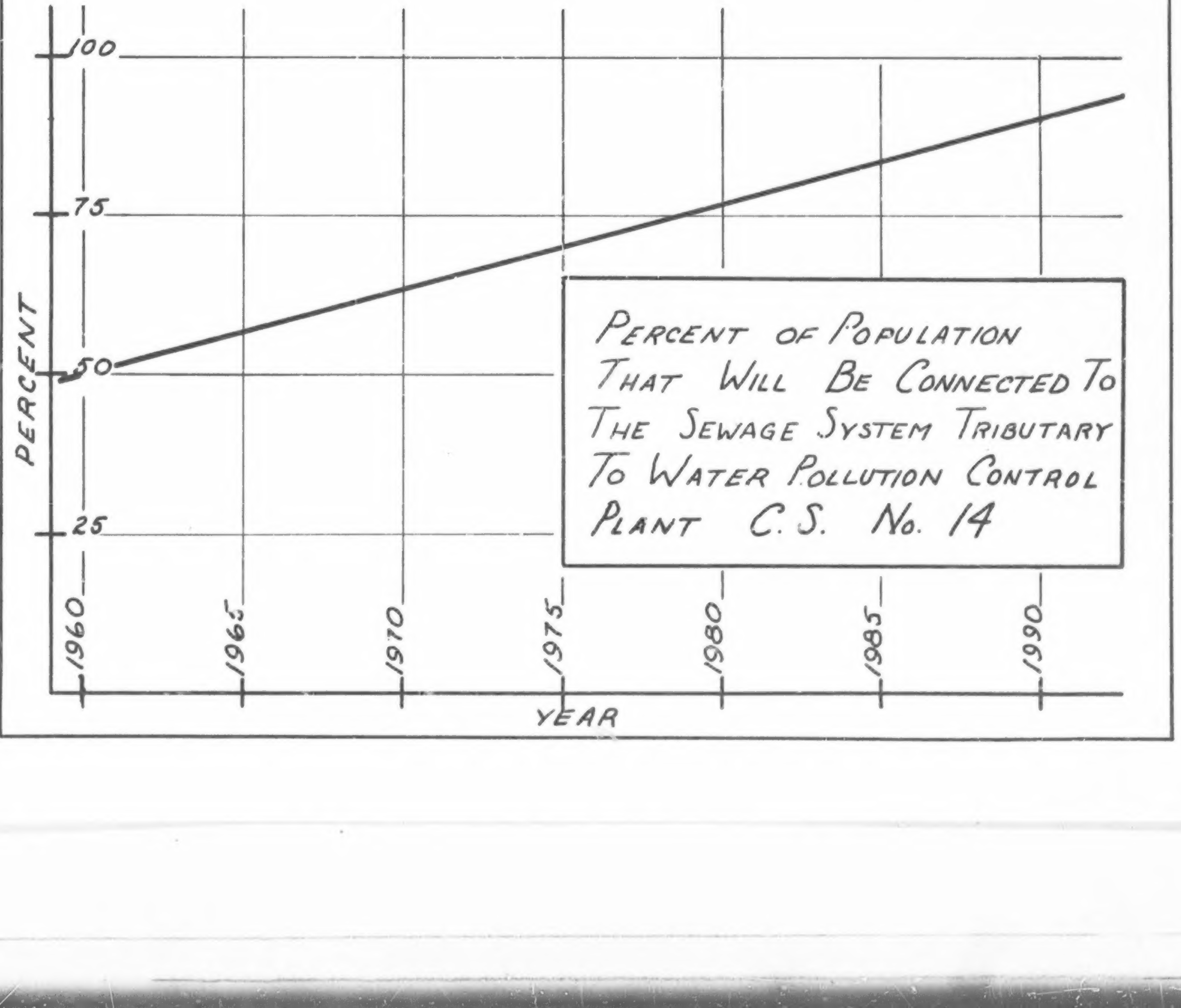
VICINITY OF LANCASTER, LOS ANGELES COUNTY, CALIFORNIA

PREPARED BY JOHN A. LAMBIE, COUNTY ENGINEER MAY 1967

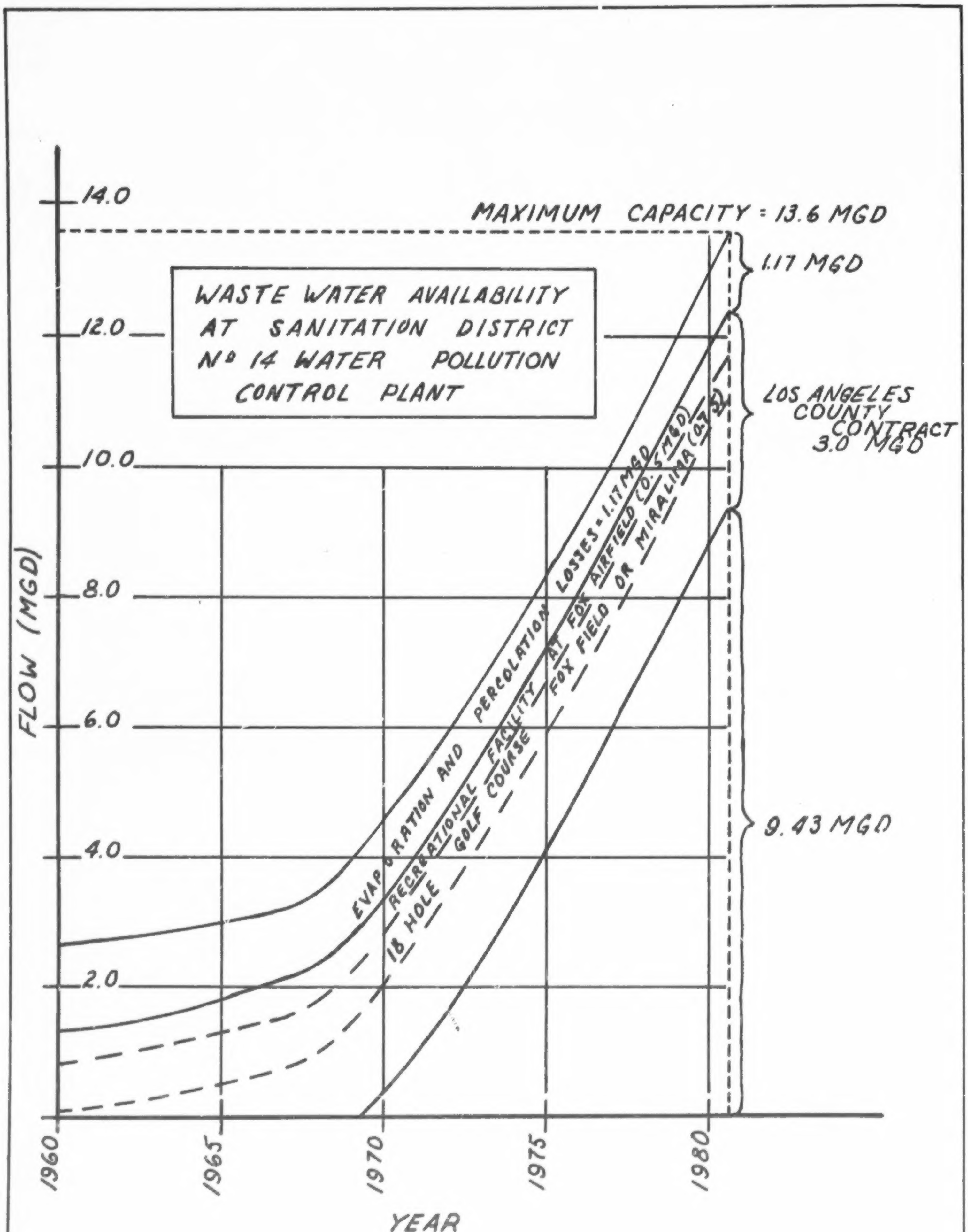




Estimated Population Of Area Tributary to L.A. County Sanitation District No. 14 W.P.C. Plant data per R.P.C. May '67



Percent of Population That Will Be Connected To The Sewage System Tributary To Water Pollution Control Plant C.S. No. 14


WASTE WATER AVAILABILITY AT SANITATION DISTRICT Nº 14 WATER POLLUTION CONTROL PLANT
MAXIMUM CAPACITY = 13.6 MGD
1.17 MGD
LOS ANGELES COUNTY CONTRACT 3.0 MGD
9.43 MGD
EVAPORATION AND PERCOLATION LOSSES = 1.17 MGD
RECREATIONAL FACILITY AT FOX AIRFIELD (0.5 MGD)
18 HOLE GOLF COURSE FOX FIELD OR MIRALIMA (0.75)
FLOW (MGD)
14.0
12.0
10.0
8.0
6.0
4.0
2.0
1960
1965
1970
1975
1980
YEAR

Antelope Valley area, Development of suitable processes for renovation of sewage influent has been the subject of Demonstration Grant Nos. WPD-50-01, WPD-50-02, WPD-50-03 and WPD-50-04 from the Federal Water Pollution Control Administration. Pathogen removal is of course a prime concern for recreational uses of the treated water. As noted in Part II, "Tertiary Treatment Process", the final product water is suitable and safe for sport fishing and boating. Development around the lakes will include picnic areas, play fields, hiking, camping and wildlife viewing. The development plan and renderings included in the following pages illustrate the intended project facilities.

It appears that this reclaimed water may be proved safe for swimming and wading after the facility is placed in operation and after further testing. At least, the results of the pilot research are encouraging, and indicate that the full scale facility will most likely be safe for body contact sports. (All State and local health standards will be strictly met before swimming can be allowed. Refer to Part IV for bacterial and viral information.)

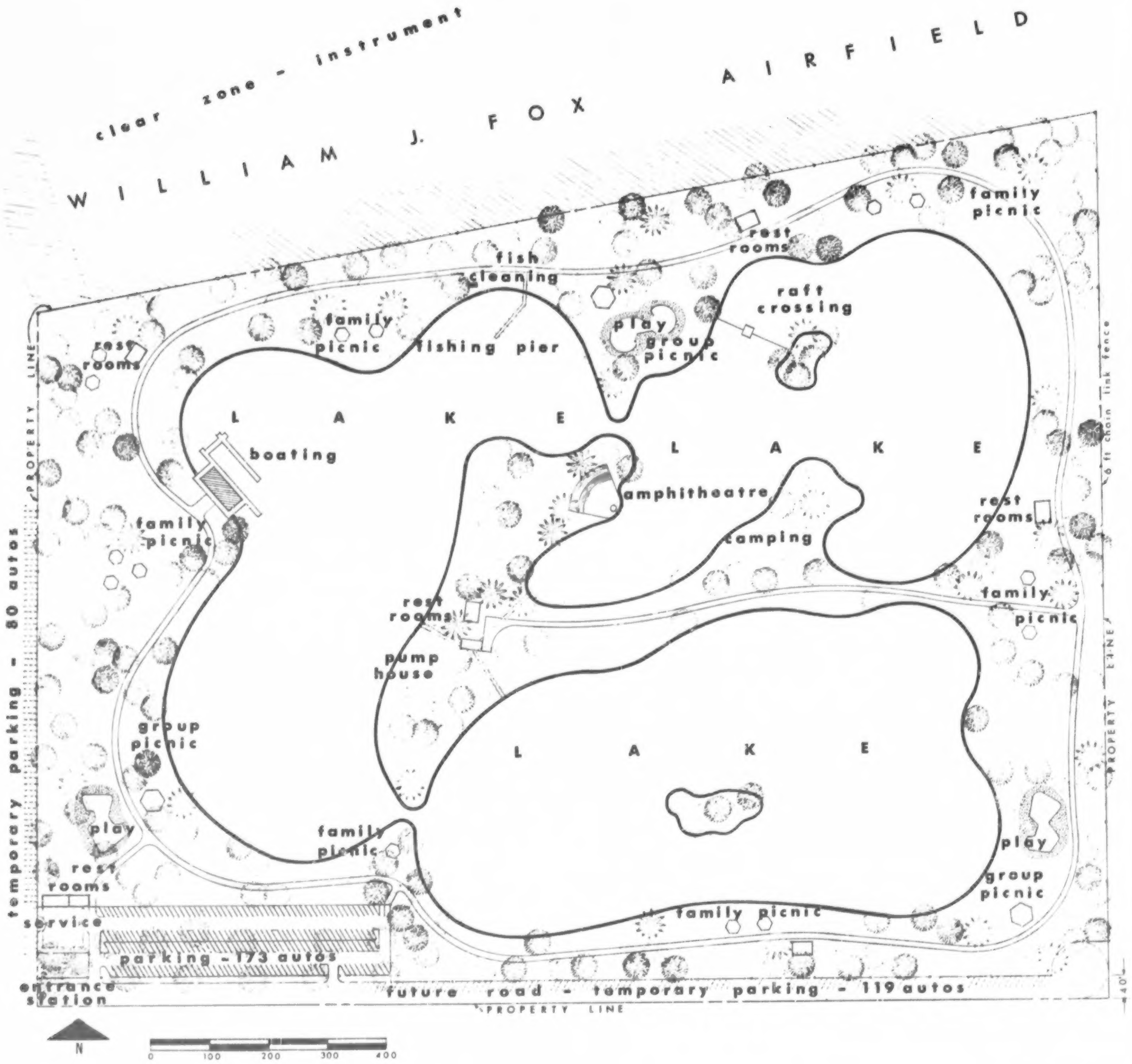
The most important aspect of this project is the economical use of reclaimed water for recreation. As the population increases, the potential supply of renovated water also increases. It is anticipated that this particular project will be the first of many similar developments. Information obtained from the successful operation of the full scale facility will be valuable source material for other projects.

C. IRRIGATION

At the present time, waste water receiving secondary treatment at the Sanitation District No. 14 Water Pollution Control Plant is wasted by evaporation.

In addition to using a portion of the plant effluent for further treatment and use in the recreation lakes, the quality of the secondary treated water (oxidation pond water) is satisfactory for golf course, park and farm land irrigation.

Considerable land in the general Lancaster area is not being cultivated, partly due to lack of water. Some farm land in the area of Palmdale, California is being irrigated by treated waste water effluent. The State

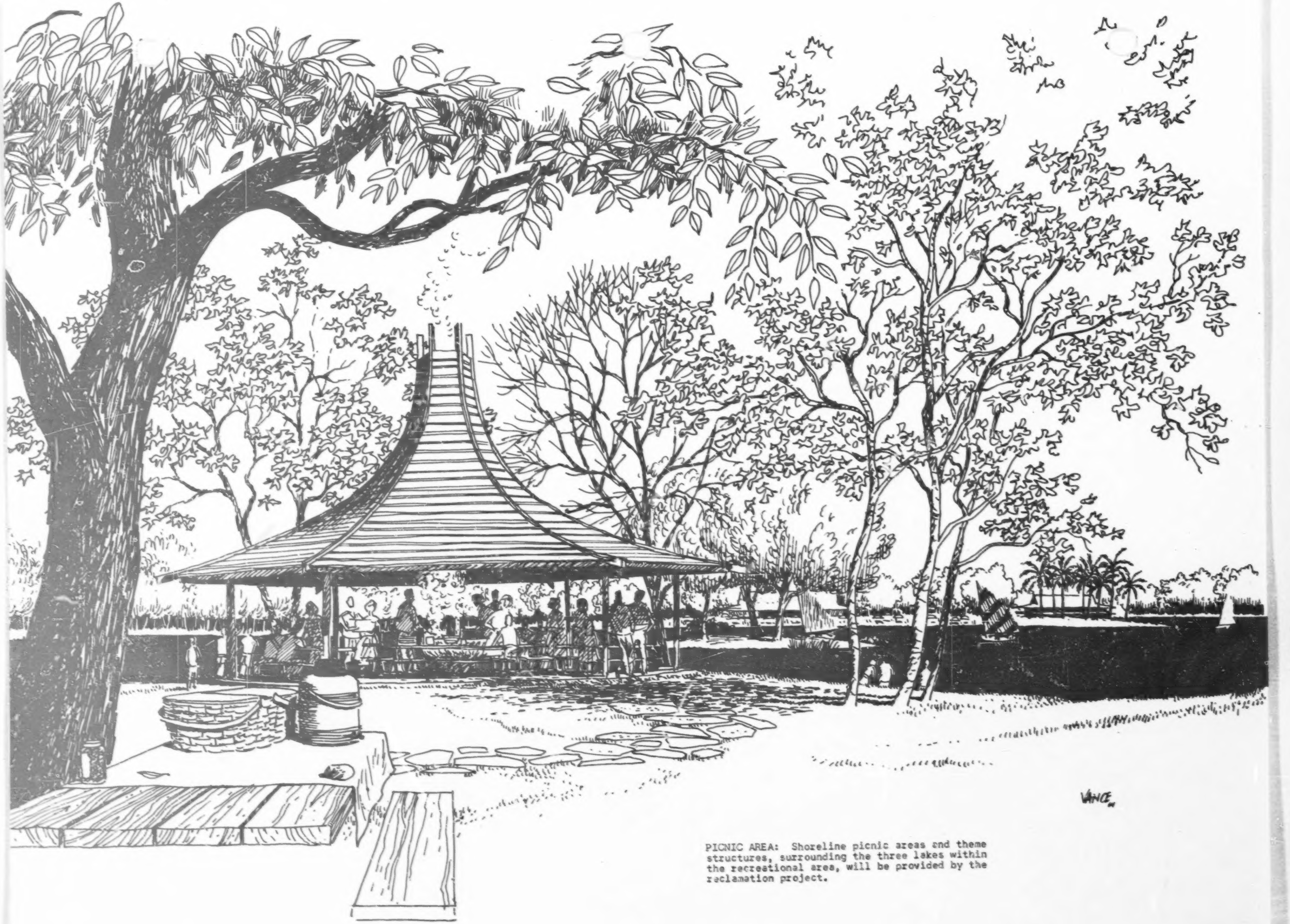

clear zone - instrument
WILLIAM J. FOX AIRFIELD
family picnic
rest rooms
fish cleaning
raft crossing
family picnic
fishing pier
play
group picnic
rest rooms
PROPERTY LINE
LAKE
LAKE
boating
amphitheatre
camping
rest rooms
6 ft chain link fence
family picnic
family picnic
rest rooms
pump house
family picnic
group picnic
LAKE
play
family picnic
play
group picnic
rest rooms
family picnic
service
parking - 173 autos
entrance station
temporary parking - 80 autos
future road - temporary parking - 119 autos
PROPERTY LINE
40'
N
0
100
200
300
400

development plan recreation area

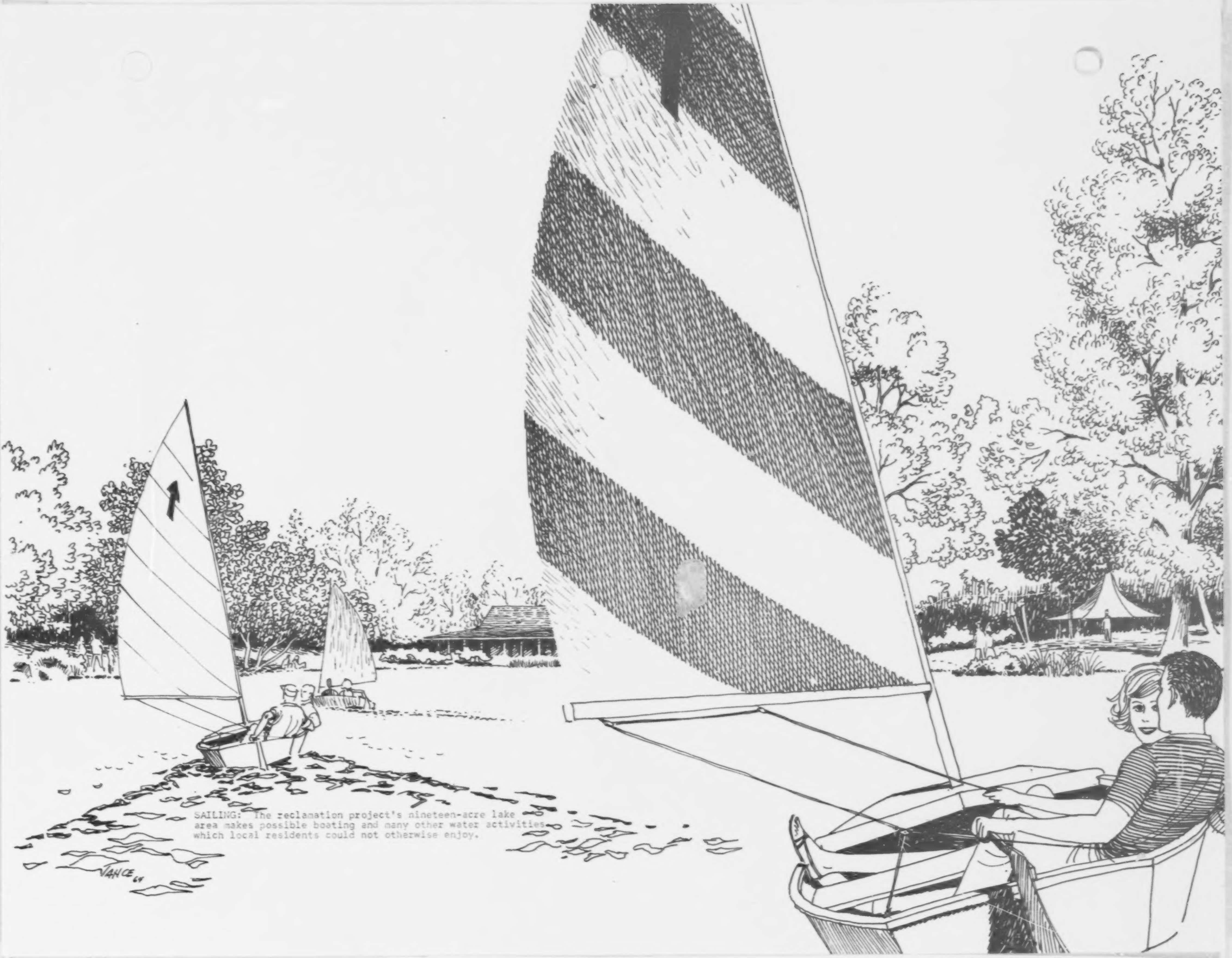
ANTELOPE VALLEY

WASTE WATER RECLAMATION PROJECT

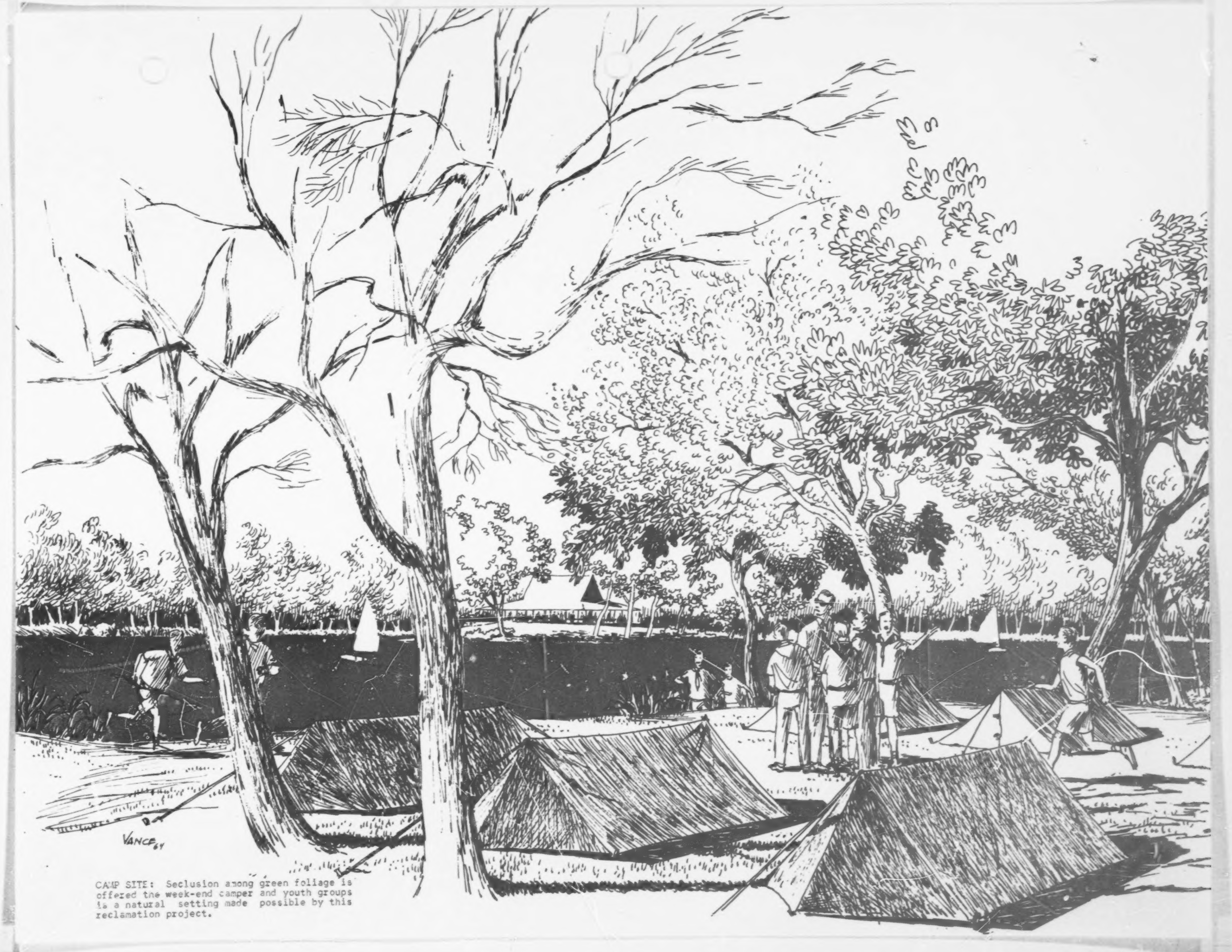
DEPARTMENT OF THE COUNTY ENGINEER - NOV 1967



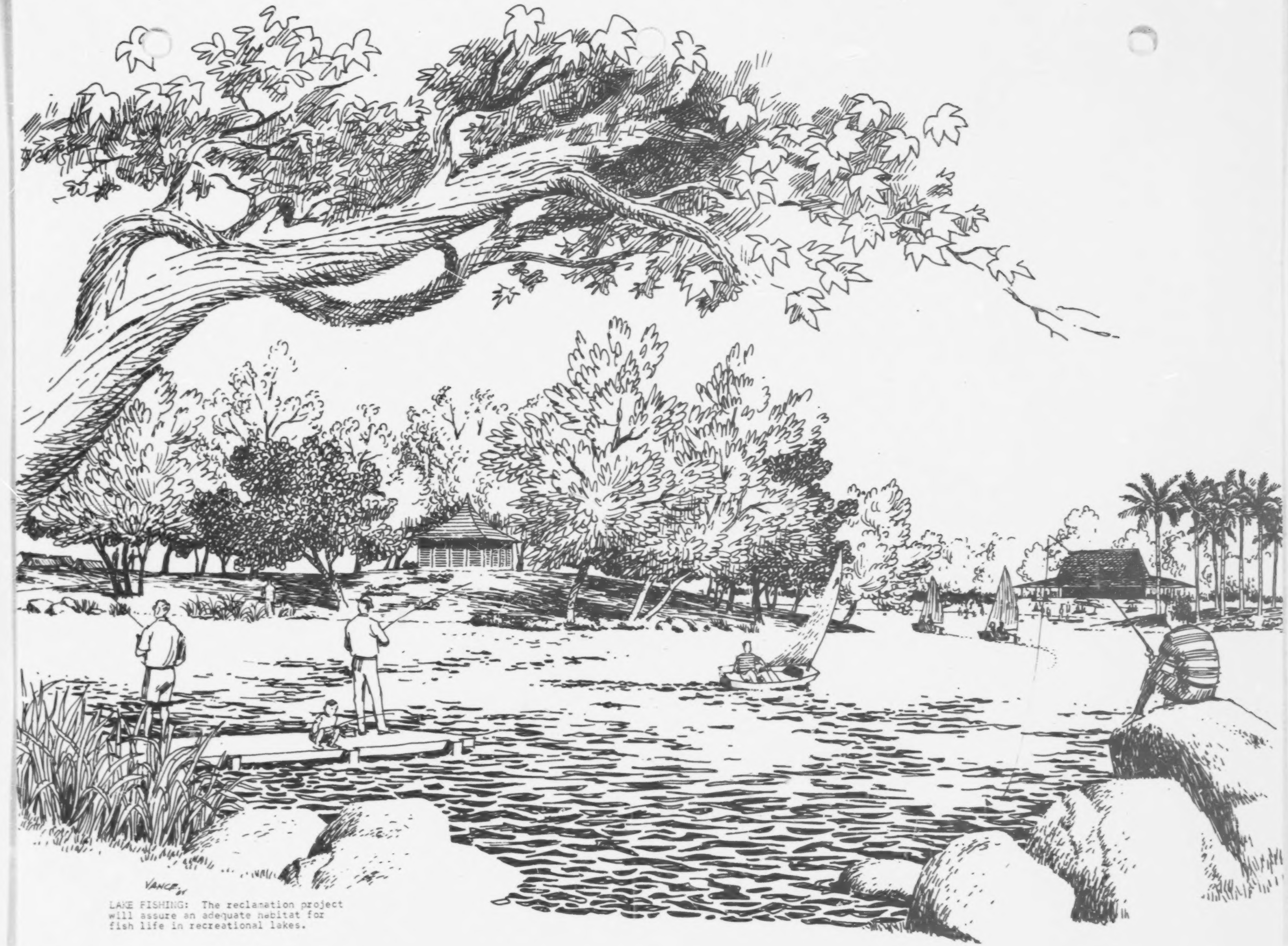
PICNIC AREA: Shoreline picnic areas and theme structures, surrounding the three lakes within the recreational area, will be provided by the reclamation project.



SAILING: The reclamation project's nineteen-acre lake area makes possible boating and many other water activities which local residents could not otherwise enjoy.



CAMP SITE: Seclusion among green foliage is offered the week-end camper and youth groups is a natural setting made possible by this reclamation project.



LAKE FISHING: The reclamation project will assure an adequate habitat for fish life in recreational lakes.

Lahontan Regional Water Quality Control Board monitors the use of such waters and imposes certain quality and health standards upon the user.

The soils consulting firm doing research in connection with the soil reclamation program analyzed both the secondary and tertiary treated waters. They report the secondary waters are of fair quality and could qualify as "Class 2 Waters." Tertiary treated water is of similar characteristic, except it is slightly more acid and has a higher concentration of sulfates.

The soils consultant concludes that no problems will arise through the use of tertiary treated water for on-site park irrigation at the Waste Water Reclamation Project. County Engineer personnel corresponded with near-by municipalities, et. al., who are already using secondary treated water for irrigation. The bulk of waste water users are irrigating golf courses and are not experiencing problems of noteworthy magnitude. All respondents to a questionnaire sent out by the Waterworks Division report that close monitoring of the flows, application rate, detention time and health standards for the treated water is imperative.

None of the agencies replying to the questionnaire had trouble free operation. However, the problems encountered generally appeared during the period the treated water was being applied for the first time. The complaint noted most often was pungent odor.

It appears that most problems arising through the use of renovated water can be solved by experience, mainly by experimentation with flow rates, ponding, spray area, spray times, and other related factors.

On the whole,the experience of other communities using secondary treated water has been good to excellent. Since good results have been achieved by other agencies using treated water, it is expected that similar results will be attained in the Antelope Valley Area.

It is well to note that permission has been given in several Southern California areas for farmers, as well as the County of Los Angeles, to use secondary treated water for irrigation at several remote centers. However, its use is limited to irrigation of trees, alfalfa, and other crops which are not consumed directly in the raw or natural state by humans.

D. INDUSTRIAL USAGE

A considerable portion of the water used in manufacturing processes is employed for operations not expressly requiring potable water.

Best use of existing supplies would indicate conservation of natural groundwater and imported potable water for domestic uses and other activities requiring potable water.

An effort has been made to determine the feasibility of using treated waste water for some industrial applications in the Antelope Valley area.

The study, conducted by the Industrial Waste Division of the Department of County Engineer, was done in three major segments. Initially a review of literature was made in order to discover what previous successes have been achieved. Next, personal visits to local manufacturers were made, with intent to determine in what areas treated waste water might be used, and what minimum quality would be required. Finally, exhaustive tests of the product water were done in order to know what minimum quality has been achieved. These studies are discussed in detail in PART V, INDUSTRIAL USAGE STUDY.

Replies from selected industries currently incorporating treated waste water in some part of the manufacturing process suggest several uses for the treated water. The use most often reported by manufacturers for treated water is for cooling. Cooling is accomplished both in a "cooling tower" and as tank dipping of parts. Effective cooling has been reported by the following industries: steel; power generation; petroleum; automobile; distilling; soap; cane and beet sugar refining.

Other applications for treated water reuse are boiler feed water, copper recovery, cleaning of processed parts, and dust control.

E. SOIL RECLAMATION

An important potential use of reclaimed water is in the area of reclamation of marginal soil. The general condition of the existing soil at the Waste Water Reclamation Project is that of a barren wasteland: The soil is highly alkaline, with critical concentration of salts and boron.

The soils consultant performed in-depth studies for the most economical method of soil reclamation. The essential data, findings and conclusions of the report are included in Part VI. The one ingredient essential to all methods of reclamation is an abundant quantity of leaching water.

Recommendations for the project site embody amending agents in conjunction with leaching.

Studies have shown that the secondary and tertiary treated water is suitable for use in soil reclamation. The successful demonstration of soil reclamation at the project site is expected to lead surrounding landowners into their own soil programs.

As the need for new productive land increases, reclamation will become more economically beneficial. Enough treated effluent is available for use in such land reclamation programs.

PART VIII

REPORTS AND ARTICLES

A. TECHNICAL REPORTS AND ARTICLES

Sufficient detailed data has been accumulated so that meaningful reports and technical articles can be prepared. The following list is a summary of reports and articles delivered during the period of the pilot testing programs.

A presentation was made by Mr. Franklin Dryden to the Los Angeles Section of the American Society of Civil Engineers entitled "Reuse of Oxidation Pond Water in Recreational Lakes", on October 29, 1965 in Los Angeles.

An article was printed in the California Water Pollution Control Association Bulletin, October, 1965 titled "Oxidation Pond Water for Recreational Use", by Franklin Dryden and Gerald Stern. This article was derived from the text of a paper presented to the California Water Pollution Control Association on the same subject, given April 30, 1965.

Mr. Dryden and Mr. Stern co-authored a third article, titled "Renovated Waste Water Creates Recreational Lake." The article appeared in the Volume 2, Number 4, April 1968 issue of Environmental Science and Technology magazine.

Mr. John D. Parkhurst published an article dealing with waste water reclamation in the April, 1965 issue of "The Bulletin." The title of the article was "A Plan for Water Re-use."

A presentation by Mr. Carl A. Lawrence, Ph.D. was made on May 18, 1967 in Santa Ana at the California State Department of Public Health's symposium on viruses in water and sewage entitled "Experiences Relating to Virus Determinations and Some of the Results."

The soils consulting firm retained by the County Engineer's Office to study soil reclamation techniques has prepared a report of findings for the County. Title of the report is "Soil Reclamation Program - Waste Water Reclamation Project for Antelope Valley Area." Preparation date of the report is January, 1968. Portions of the report appear in PART VI, SOIL RECLAMATION STUDIES.

Results of the County Health Department studies concerning bacterial and viral contamination at various stages of treatment, including radio-active tracer studies of flow patterns in the oxidation ponds is contained in PART IV, BACTERIOLOGICAL AND VIROLOGICAL STUDIES.

In addition to the above presentations of data, Interim and Annual Reports have been prepared by the County Engineer's Office and forwarded to the Federal Water Pollution Control Administration, Department of Interior. The dates of these reports are as follows:

March 1, 1965	Interim Progress Report
March 17, 1965	Special Review and Report
June 1, 1965	First Annual Progress Report
February 28, 1966	Interim Progress Report
April 21, 1966	Special Review and Report
June 14, 1966	Second Annual Progress Report
May 1, 1967	Interim Progress Report
June 14, 1967	Third Annual Progress Report

B. PUBLIC PRESENTATIONS

Every attempt has been made to acquaint the residents of the area with the project. The enthusiastic acceptance has been very gratifying. This program included the following presentations by the County Engineer staff to the listed organizations:

1. Lancaster Optimist Club--3
2. Lahontan Regional Water Pollution Control Board--3
3. Mariposa School PTA--Lancaster
4. California Water Pollution Control Association
5. Antelope Valley Progress Association--2
6. Lancaster Chamber of Commerce--2
7. Del Sur Grange--Lancaster
8. Antelope Valley Industrial Fair
9. Antelope Valley Republican Womens' Club
10. Pomona Grange--Lancaster
11. Quartz Hill Womens' Club
12. Antelope Valley YMCA
13. President's Water Pollution Control Advisory Board--Los Angeles
14. County Water Resources and Reclamation Advisory Commission
15. Pearblossom Chamber of Commerce
16. Mariners Class, Presbyterian Church, Lancaster
17. Presbyterian Church of Lancaster
18. Sixth grade classes at Sierra School, Lancaster

C. NEWS MEDIA PUBLICITY

Support of this project by the news media has been most encouraging. Following is a tabulation of news presentations.

1. NEWSPAPERS AND MAGAZINES

Since 1962 the following newspapers and magazines have carried the number of indicated articles regarding this particular project:

1.	Antelope Valley Press	32
2.	Antelope Valley Ledger-Gazette . . .	18
3.	Herald-Examiner	11
4.	Los Angeles Times	7
5.	County Engineer's News Letter	4
6.	Valley Times	1
7.	Park Maintenance Magazine	1
8.	Desert Spectator Magazine	1
9.	Feather River Project Association News Letter	1
10.	Engineering News-Record Magazine . . .	1
11.	Water & Sewage Works Magazine	1
12.	Water in the News Newsletter	1
13.	So. Antelope Valley Foothill News . .	1
14.	The Wall Street Journal	1
15.	The Valley News	1
16.	"Sewer Leaks" Magazine	1

2. RADIO AND TELEVISION

The following broadcasts concerning this project have been presented:

1. KAVL Lancaster--Public Service--June, 1962
2. KRKD Los Angeles--Property Owner's Tax Association--January, 1963
3. KABC-TV Public Service--June, 1963
4. KRKD Los Angeles--Property Owner's Tax Association--November, 1963
5. KRKD Los Angeles--Property Owner's Tax Association--February, 1965

D. INFORMATION REQUESTS

Many requests have been received from organizations and individuals for further information on the project. These have been from all over the United States as follows:

1.	Los Angeles County	65
2.	California (other than Los Angeles County)	17
3.	Indiana	1
4.	Arizona	3
5.	Oregon	1
6.	New Jersey	1
7.	New York	1
8.	Hawaii	2
9.	Washington, D. C.	2
10.	Pennsylvania	1
11.	Ohio	1
12.	Kansas	1
13.	Florida	1

PART IX

PROJECT PERSONNEL AND BIOGRAPHICAL DATA

A. PERSONNEL

The following personnel have worked as the project staff during the pilot test period. The portion of the average work load for the individual spent working on the project is included as per cent of total work time. Persons denoted by * have biographical data included in Section B.

DEPARTMENT OF COUNTY ENGINEER

*1. John A. Lambie - Project Director, County Engineer, 1% of time.

*2. Richard E. Kuhns - Assistant Project Director, Division Engineer, Sanitation Division, 10% of time.

3. Clifford H. Hughes - Assistant Project Director, (Retired) Division Engineer, Sanitation Division, 3% of time.

*4. Richard M. Cron - Supervising Civil Engineer, Sanitation Division, 3% of time.

5. Henry Lee - Civil Engineer, Sanitation Division, 5% of time.

*6. Rudolph J. Yelinek - Associate Civil Engineer, Sanitation Division, 10% of time.

7. R. David Sievert - Civil Engineering Associate, Sanitation Division, 20% of time.

8. Shurlo D. Tooker - Senior Civil Engineering Assistant, Sanitation Division, 30% of time.

9. Kenneth N. Weber - Senior Civil Engineering Assistant, Sanitation Division, 1% of time.

10. William Samborski - Civil Engineering Assistant, Sanitation Division, 35% of time.

11. Floyd Combs - Civil Engineering Assistant, Sanitation Division, 10% of time.

12. Ralph H. Clark - Civil Engineering Assistant, Sanitation Division, 1% of time.

*13. Carroll D. Smith - Division Engineer, Industrial Waste Division, 1% of time.

*14. Charles G. Brisley, Jr. - Supervising Civil Engineer, Industrial Waste Division, 1% of time.

*15. Kenneth Harvey - Civil Engineer, Industrial Waste Division, 10% of time.

16. David C. Edmondson - Civil Engineer, Industrial Waste Division, 1% of time.

17. Chester J. Falicki - Civil Engineering Associate, Industrial Waste Division, 3% of time.

18. Nathan Berman - Civil Engineering Associate, Industrial Waste Division, 10% of time.

19. Clarence L. Persons, Sr. - Industrial Waste Chemist, Industrial Waste Division, 4% of time.

20. Paul Vincent - Industrial Waste Chemist, Industrial Waste Division, 3% of time.

21. Lemuel D. McDaniel, Jr. - Industrial Waste Inspector, Industrial Waste Division, 2% of time.

COUNTY HEALTH DEPARTMENT

*1. Gerald A. Heidbreder, M.D., M.P.H. - County Health Officer, 1% of time.

*2. Donald Suggs - Public Health Engineer, 4% of time.

*3. H. L. Messier - Assistant Director, Bureau of Environmental Sanitation, 3% of time.

*4. Carl A. Lawrence, Ph.D. - Director, Bureau of Laboratories, 5% of time.

5. Marshall Mosher - Chief Sanitarian, 1% of time.

6. Stanley Holmes - Senior Sanitarian, 4% of time.

7. Elaine De Boynton - Assistant Director, Bureau of Laboratories, 5% of time.

8. William G. Waldron - Senior Biologist-Entomologist, 10% of time.

9. Aiko Butsumyo - Senior Public Health Microbiologist (Virologist), 10% of time.

10. Marion Mormino - Public Health Microbiologist, 30% of time.

11. Chhaganbhai Bahkta - Public Health Microbiologist, 30% of time.

12. Donald Dupre, - Public Health Microbiologist, 50% of time.

13. Ruth Killingsworth - Public Health Microbiologist, 1% of time.

14. Arthur Frierson - Clinical Laboratory Technologist, 45% of time.

15. Shirlene Everett - Clinical Laboratory Technologist, 60% of time.

COUNTY SANITATION DISTRICTS

*1. John D. Parkhurst - Chief Engineer and General Manager, County Sanitation Districts, 1% of time.

*2. Walter E. Garrison - Assistant Chief Engineer, 1% of time.

*3. Franklin D. Dryden - Deputy Assistant Chief Engineer, Sewage Treatment & Water Reclamation, 10% of time.

*4. Charles Carry - Supervising Civil Engineer, Research and Development, 5% of time.

5. John Ferguson - Assistant Project Engineer, Division of Research and Development, 50% of time.

6. Jay Kremer - Assistant Project Engineer, Division of Research and Development, 25% of time.

7. Ricardo Tejidor - Chemist, Division of Research and Development, 90% of time.

8. Martel Durazo - Assistant Chemist, Division of Research and Development, 90% of time.

9. James Steinert - Laboratory Technician, Division of Research and Development, 60% of time.

10. David Hewitt - Laboratory Technician, Division of Research and Development, 90% of time.

11. Ernest Freeman - Field Technician, Division of Research and Development, 40% of time.

12. Charles Dalton - Field Technician, Division of Research and Development, 75% of time.

13. Bill Parsonson - Field Technician, Division of Research and Development, 10% of time.

14. George Martin - Treatment Plant Operator, 25% of time.

OTHERS

*1. Harvey F. Ludwig, Ph.D. - President, Engineering-Science, Inc., 1% of time.

2. Robert H. White - Vice President, Engineering-Science, Inc. 1% of time.

*3. H. Esmalli - Soil Scientist, Engineering-Science, Inc., 35% of time.

4. L. W. Adams - Civil Engineer, Engineering-Science, Inc., 1% of time.

5. William Bishop - Engineering Scientist,Engineering-Science, Inc., 2% of time.

6. Ralf Carter - Engineering Scientist, Engineering-Science, Inc., 1% of time.

7. D. R. Anderson - Engineering Scientist, Engineering-Science, Inc., 2% of time.

8. Gerald Stern - Chemical Engineer, USPHS, 10% of time.

9. Robert Toth - Fish Pathologist, State Department of Fish and Game, 1% of time.

10. Andrew L. Gram - Ph. D. - Vice President, Molina Engineering Consultants, Inc., 5% of time.

B. BIOGRAPHICAL DATA

A brief biographical review follows for the key personnel who have worked on this project.

COUNTY ENGINEERING DEPARTMENT

JOHN A. LAMBIE - PROJECT DIRECTOR, County Engineer, Los Angeles County.

Mr. Lambie was graduated from the University of Southern California in 1935 with a B.S. degree in Civil Engineering and in 1938 received a M.S. degree in Civil Engineering. He is a Registered Civil Engineer in the State of California.

He began his County service for the then Department of Building and Safety as an engineering clerk in December 1935. Subsequently he was promoted to the various grades of Building Inspector and Engineer. In 1941 he was appointed District Engineer in the Antelope Valley office at Lancaster. Later he was transferred to Altadena and the West Hollywood offices, serving in the same capacity.

Mr. Lambie was commissioned in the U. S. Marine Corps in 1942 and served as an engineering and construction officer in the construction of large airports, headquarters camps and supply depots.

Upon returning to civilian duties with the Department of Building and Safety in 1946, Mr. Lambie was promoted to structural research engineer later that year.

After the consolidation of all engineering departments except the Road Department and the Los Angeles County Flood Control District into the Department of County Engineer and Surveyor, Mr. Lambie was appointed Assistant Chief Deputy County Engineer in 1952.

On September 27, 1955 the Los Angeles County Board of Supervisors appointed him County Engineer, which position he now holds.

Mr. Lambie is a member of the following professional organizations and committees:

American Public Works Association; President 1967-68
APWA "Top Ten Public Works Man-of-the Year", 1960.

National Association of County Engineers, President 1960-61

American Society of Civil Engineers

American Right of Way Association

National Institute for Solid Wastes

National Institute for Municipal Engineering

City and County Engineers' Association

County Engineers Association of California, President 1966-67

Structural Engineers' Association of Southern California

Mr. Lambie has served on citizens advisory committees to the United States Senate (1957), California State Senate (1963), California Department of Public Health (Chairman of Sanitary Engineering Advisory Committee 1959) and the United States Surgeon General (Water Pollution Control Research, 1968). In 1966, he was selected to represent the United States at the Third International Conference on Water Pollution Research at Munich, Germany.

RICHARD E. KUHNS - Assistant Project Director, Division Engineer, Sanitation Division, Department of County Engineer, Los Angeles County.

Graduated from the California Institute of Technology in 1944 with a B.S. degree in Civil Engineering. Completed several post graduate courses in hydraulics and soil mechanics at the University of Southern California. Attended training program at the Robert Taft Sanitary Engineering Center in 1956.

He recently retired as a Lt. Commander in the Naval Reserve after completion of 23-years service in the Civil Engineering Corps.

He began work with the Department of County Engineer in 1946. He has had 16-years experience with the Sanitation Division in the design of sewerage systems, pumping stations and treatment plants, and is now Division Engineer in charge of all maintenance operations and design of all sewerage facilities and treatment plants in County territory and 32 Contract Cities. He also served five years as an Administrative Civil Engineer administrating County Engineer activities in the Antelope Valley region and cities where the County Engineer is the City Engineer.

He is a Registered Civil Engineer with the State of California and is a member of the American Public Works Association and the Water Pollution Control Association. He has been an associate member of ASCE, Honorary member of the Building Contractors Association, and member of the Society of Military Engineers.

CARROLL D. SMITH - Division Engineer, Industrial Waste Division, Department of County Engineer, Los Angeles County.

Mr. Smith received his B.S. degree from the University of Southern California in 1952. He has also completed post-graduate work in hydraulics, structural design and soil mechanics.

He has been associated with the Department of County Engineer since 1952 with varying degrees of responsibility in hydraulic design, structural design of hydraulic structures, control of industrial wastes and sanitary land fills.

His responsibilities have included the supervision of the Department's Subdivision, Drainage and Investigations Section; the supervision of the Grading Section and administration of the County's Grading Ordinance; and administration of the County Engineer's Contract City Program, whereby various engineering services are provided to many of the cities in the County.

He is a Registered Civil Engineer with the State of California and is a member of the American Public Works Association and the City and County Engineers Association.

RICHARD M. CRON - Supervising Civil Engineer, Sanitation Division, Department of County Engineer, Los Angeles County

Mr. Cron has attended Pasadena City College, East Los Angeles College, the University of California at Los Angeles, and the University of Southern California, majoring in Civil Engineering.

He has been with the Department of County Engineer since 1951, and his professional responsibilities have been in the Design Division, the Industrial Waste Division, and the Sanitation Division, where he is the Assistant Division Engineer.

He is a Registered Civil Engineer in the State of California and is a member of the American Public Works Association and the California Water Pollution Control Association.

CHARLES G. BRISLEY, JR. - Supervising Civil Engineer, Industrial Waste Division, Department of County Engineer, Los Angeles County.

Mr. Brisley received his B.S. in Civil Engineering from the University of Missouri in 1950. He is a member of Chi Epsilon, the Honorary Civil Engineering Fraternity. His major professional interest is in public works--administration and engineering.

He has been with the Department of the County Engineer since September 1953 and has been associated with the design and construction of sanitary and storm drain systems, as well as the construction of buildings and other major facilities in the County's extensive capital project program. His responsibilities have included contract administration supervision of the Technical Consultants and Engineering Construction Sections of the Construction Division; supervision of the Capital Projects Design Section of the Design Division. His earlier assignments included the preparation of specifications and construction estimates for major storm drain facilities.

He is a Registered Civil Engineer in the State of California and is a member of the American Society of Civil Engineers. He has represented this department on the Joint Committee for Standard Public Works Specifications, sponsored by the Southern California Chapter of the American Public Works Association and the Associated General Contractors.

KENNETH HARVEY - Civil Engineer, Industrial Waste Division, Department of County Engineer, Los Angeles County.

Mr. Harvey graduated with a B.S. degree in Civil Engineering received from the University of Southern California. His main field of interest and study centered around hydrology and hydraulics. He is also a Registered Civil Engineer with the State of California.

He has been associated with the Department of County Engineer since 1951. His work involved hydraulic design of structures and the preparation of estimates and construction specifications for storm drain systems. He also worked in the Department's Subdivision, Drainage and Investigation Section.

He formerly supervised a section responsible for the checking of industrial plans for waste treatment control facilities. He was responsible for the chemical analysis of industrial wastes and potable water supplies for the purpose of determining conformance with quality requirements.

Currently, Mr. Harvey serves as Section Head of the Permits and Special Investigations Section of the Industrial Waste Division. This section is responsible for issuing permits for connection to public sewers, et. al. to industrial users.

RUDOLPH J. YELINEK - Associate Civil Engineer, Sanitation Division, Department of County Engineer, Los Angeles County.

Mr. Yelinek graduated from the University of Southern California in 1959 with a B.S. degree in Civil Engineering.

He has been with the County Engineer since 1946 and has been associated in the field of sanitary engineering for the past 18 years with varying degrees of responsibility. In his present position he is in charge of a major design section and is responsible for the checking and design of pumping stations, treatment plants and specialized sewerage systems.

Mr. Yelinek is a Registered Civil Engineer with the State of California and is a member of the California Water Pollution Control Association.

COUNTY HEALTH DEPARTMENT

GERALD A. HEIDBREDER, M.D., M.P.H. - Health Officer
Health Department, Los Angeles County.

Dr. Heidbreder graduated in 1932 from the University of California Medical School and served his internship in the San Francisco City and County Hospital. In 1941, he received the degree of Master of Public Health from John Hopkins School of Public Health and Hygiene.

He was engaged in the public health field in varied capacities in Federal, State and local agencies before joining the Los Angeles County Health Department in 1945 where he served as Chief of Division of Venereal Disease Control, Chief of Division of Acute Communicable Diseases and Chief Deputy Health Officer. Dr. Heidbreder was appointed to his present position on July 12, 1966.

He is a member of the American Medical Association and the State and County Medical Associations, Fellow of the American Public Health Association, Diplomate of the American Board of Preventive Medicine, Assistant Clinical Professor in the Department of Microbiology and Virology at U.C.L.A., and lecturer in Public Health at University of Southern California, Loma Linda University and Los Angeles State College.

DONALD SUGGS - Administrative Public Health Engineer,
Health Department, Los Angeles County.

Mr. Suggs graduated from the University of Oklahoma in 1934 with a degree in Civil Engineering and from the University of North Carolina in 1952 with a M.S. in Public Health majoring in Sanitary Engineering.

He has had varied experience in the sanitary engineering field, having spent seven years as consulting sanitary engineer with the firm of Clyde Kennedy of San Francisco. Also, prior to his present position of Public Health Engineer, he has had nineteen years of sanitary engineering experience with the State of California and local agencies.

Mr. Suggs is a Registered Civil Engineer with the State of California and currently is a member of the Sanitary Advisory Committee to the California State Board of Health.

HENRY L. MESSIER - Assistant Director, Bureau of Environmental Sanitation, Health Department, Los Angeles County.

Mr. Messier graduated with a B.S. degree from the University of California at Los Angeles in 1935. He also completed several post-graduate courses in public health engineering at the University of Southern California and University of California at Berkeley.

He began work with the Los Angeles County Health Department in 1936, in public health engineering where he has accomplished considerable work in insect control.

He has taught courses in public health engineering for several years at the University of Southern California and East Los Angeles City College. Mr. Messier is a member of the Water Pollution Control Association and National Association of Sanitation.

CARL A. LAWRENCE - Ph.D. - Director, Bureau of Public Health Laboratories, Health Department, Los Angeles County.

Dr. Lawrence received his education at the University of Michigan where he earned the degrees of B.S. in Pharmacology in 1932, M.S. in Microbiology in 1935 and Ph.D. in Microbiology in 1937.

After being an Associate Microbiologist in the Bureau of Laboratories of the Maryland State Health Department, he became the Director of Bacteriological Research and Control Laboratory at Winthrop Chemical Company in Rensselaer, New York until 1948. From 1948 to 1953 he was an Assistant Professor of Medical Bacteriology at the University of Michigan. He was appointed to his present position in 1953. Since 1955 he has also served as Associate Professor in the Department of Microbiology and Immunology at the University of California Medical Center in Los Angeles.

During his professional career Dr. Lawrence had published about 70 papers dealing with bacteriology and chemotherapy.

Dr. Lawrence is a member of a number of professional societies including California Association of Laboratory Directors, State and Provincial Laboratory Director's Conference, American Society of Microbiologists, Society of Experimental Biology and Medicine, Phi Sigma Biological

Society, American Pharmaceutical Association, American Public Health Association, New York Academy of Science and Royal Society of Health (Great Britain).

COUNTY SANITATION DISTRICTS

JOHN D. PARKHURST - Chief Engineer & General Manager, Sanitation Districts of Los Angeles County.

Mr. Parkhurst received his B.S. in Civil Engineering from the University of California in 1942.

He was a commissioned officer in the United States Public Health Service assigned to Malaria Control during World War II. Following the war he spent one year (1946) on a special sewerage survey for Orange County, California, in preparation of a comprehensive survey and report of master plan for a sewerage and disposal system for all of Orange County. Since 1947 Mr. Parkhurst has been a member of the engineering staff of the Los Angeles County Sanitation Districts working in various capacities as Assistant Engineer of Design; Resident Engineer in charge of construction; Division Engineer in charge of all field operations, including operation and maintenance; and Assistant Chief Engineer in charge of all operations pertaining to water reclamation, sewerage and sewage disposal before becoming Chief Engineer and General Manager in 1961.

Mr. Parkhurst has the overall responsibility as Chief Engineer and General Manager of the organization which provides sewerage, wastewater reuse, and refuse disposal sites for approximately 7 million people living in all or a part of 70 cities and large unincorporated tracts within a 700 square mile area in Los Angeles County.

Mr. Parkhurst is a registered Civil Engineer in the State of California, CE 7215, and a Diplomate of the American Academy of Environmental Engineers.

He is also a:

Member, American Public Health Association
Member, American Public Works Association
Fellow, American Society of Civil Engineers
Member, Water Pollution Control Federation
Member, Federal Water Pollution Control Advisory Board

WALTER E. GARRISON - Assistant Chief Engineer, Los Angeles County Sanitation Districts.

Mr. Garrison graduated with a B.S. degree in 1948 from Cooper Union in New York City.

Since 1948, Mr. Garrison has been employed by the County of Los Angeles Sanitation Districts as a Sanitary Design Engineer and Supervising Civil Engineer in charge of Research and Development. In his most recent position as Deputy Assistant Chief Engineer, Mr. Garrison was in charge of all sewerage construction, operation and maintenance of sewage treatment and water reclamation. One of his more recent achievements was the supervision of the planning and design of the Whittier Narrows Reclamation Project.

Mr. Garrison is a member of the Tau Beta Pi and Chi Epsilon and also a member of the American Society of Civil Engineers and the California Water Pollution Control Association. He is a Registered Civil Engineer with the State of California.

FRANKLIN D. DRYDEN - Deputy Assistant Chief Engineer, Los Angeles County Sanitation Districts.

Mr. Dryden graduated from the California Institute of Technology with a B.S. degree in Engineering in 1954 and with a M.S. degree in Engineering in 1957.

After a brief period of employment with the California State Department of Public Health, he served two years in the military as Installations Engineer on Air Force bases in California. He received a U.S. Public Health Service Scholarship in 1956. He has been employed by the County Sanitation Districts since 1957. Prior to assuming his present duties in charge of all sewerage and water reclamation activities he served as Division Engineer in charge of research and development.

He is an Associate Member of the American Society of Civil Engineers, a member of the California Water Pollution Control Association and a Registered Civil Engineer in the State of California.

CHARLES W. CARRY - Supervising Civil Engineer for Research and Development, Los Angeles County Sanitation Districts

Mr. Carry graduated from Loyola University of Los Angeles with a B.S. degree in Engineering in 1960 and from the California Institute of Technology with a M.A. degree in Engineering in 1961.

He has been employed by the County Sanitation Districts since 1961 and has previously been engaged in the design of treatment plants and has served as Resident Engineer in charge of field engineering.

He is a member of the California Water Pollution Control Association and is a Registered Civil Engineer in the State of California.

Others

HARVEY F. LUDWIG - President, Engineering-Science, Inc., Arcadia, California

Mr. Ludwig is a sanitary engineer of national and international stature. His extensive experience in consulting, academic, and administrative capacities has included most of the technical competencies of the sanitary engineering field.

In the period from 1938 to 1942 he obtained B.S. and M.S. degrees from the University of California, and gained a variety of experience in water supply and sewerage engineering. In World War II, as a U.S. Public Health Service Officer, he directed Aedes aegypti control in the United States, and served as sanitary engineer with the Balkan and Jugoslav missions of UNRRA.

From 1949 to 1951 he was Associate Professor of Sanitary Engineering at the University of California, and from 1952 to 1956 returned to the U.S. Public Health Service as Sanitary Engineer Director, Office of Engineering Resources. In 1957 he organized Engineering-Science, Inc., of which he is president. This firm specializes in waste water reclamation and the development of new treatment processes.

Mr. Ludwig has contributed over 50 papers on sanitary engineering subjects. He is one of the founders of the American Academy of Sanitary Engineers and of the Conference of Federal Sanitary Engineers, and is a member of several professional committees of the ASCE, AWWA and WPCF.

HOUSHANG ESMAILI - D. Eng. - Research Engineer,
Engineering-Science, Inc.,
Arcadia, California

Dr. Esmaili received a Bachelor of Science degree in Agricultural Science from the University of Tehran, Iran in 1960. Post graduate studies resulted in a Master of Science degree in Irrigation Science, 1962, and a Doctor of Engineering degree in Irrigation Drainage and Water Resources Engineering, 1966. Both degrees were conferred by the University of California, Davis.

While studying at U.C., Davis, Dr. Esmaili was employed by the University as a Teaching Assistant in the areas of soil and water management and irrigation system design. In addition, Dr. Esmaili participated as a research assistant in various research projects embracing the field of irrigation and groundwater science.

Since joining Engineering-Science, Inc. in 1966, Dr. Esmaili has been the project engineer for that firm's study of soil reclamation methods for the Antelope Valley Waste Water Reclamation Project. He is also the project engineer for a comprehensive groundwater study in the Fresno area of California's Central Valley.

The study proposes to determine optimum methods of integrating groundwater and surface water resources.

Dr. Esmaili has also participated in the Fresno solid waste management study on the evaluation of agricultural wastes and methods of disposal.

PART X

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The following references were consulted during the research and development of the pilot test facilities. Some of the references cited provided testing methods and standards, as well as descriptive material. This review of available literature was helpful in determining the course of testing and in avoiding duplication of research efforts.

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